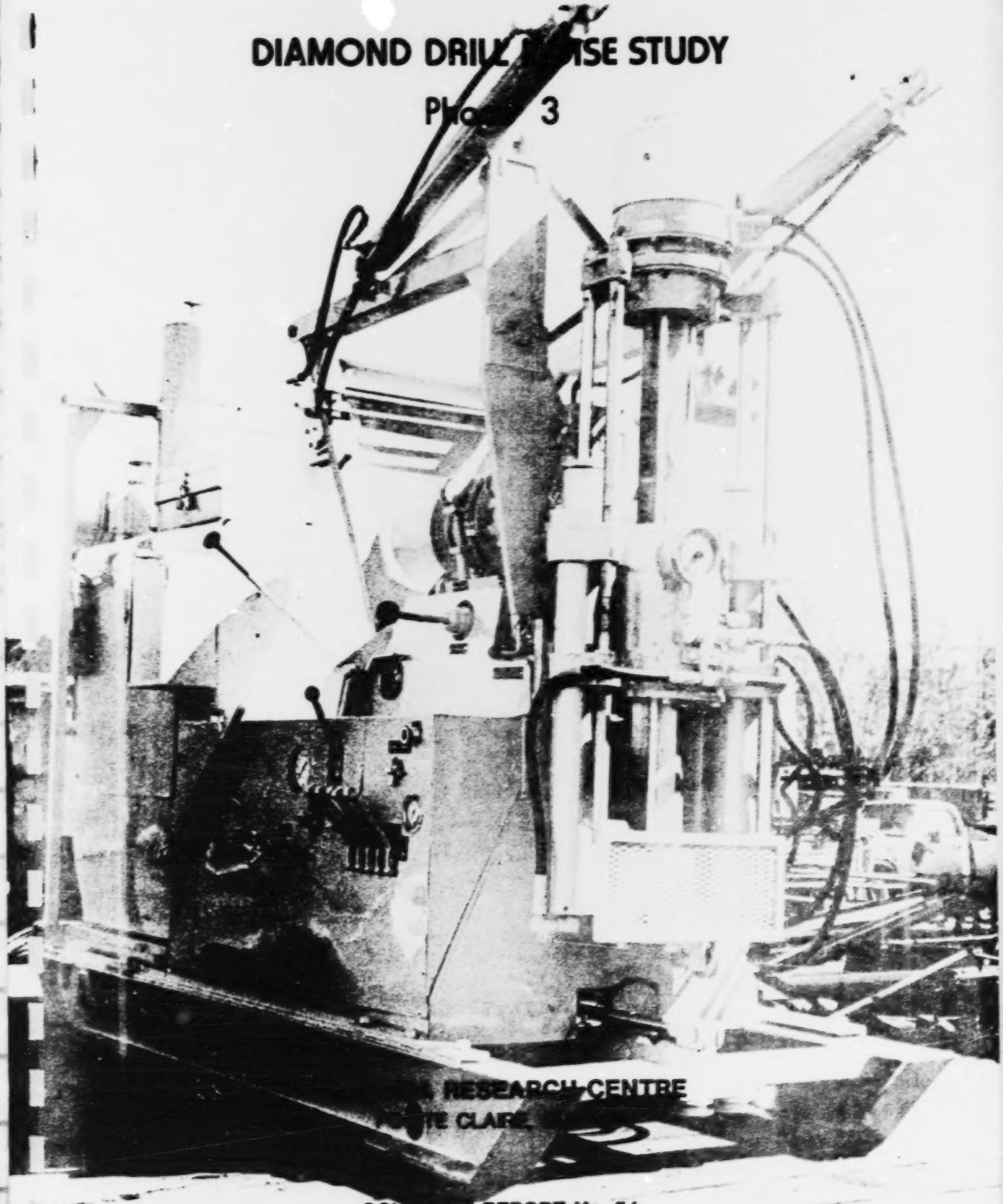
DIAMOND DRILL NOISE STUDY

Phase 3



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COST EFFECTIVENESS AND TECHNICAL FEASIBILITY OF OPTIONS AVAILABLE FOR SOUND-PROOFING DIAMOND DRILLING EQUIPMENT - PHASE 3

(DSS Contract 14SQ.23440-1-9045)

MARCH 1983

by

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On behalf of

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Special thanks are also offered to Midwest Drilling Co. of Winnipeg for the loan of a BBS-37 drill to CANMET for the purpose of the above study, to Mr. G. Wright and staff of Logan Drilling Limited in Musquodoboit, N. S., for their helpful comments and assistance, to Messrs. C. Smith and M. Smith of Wallace, N. S., for allowing an intrusion into their normal drilling operation for the benefit of science and fellow drillers, to Mr. R. Laporte and staff of St. Lambert Drilling Co. Ltd. and staff of Sprague and Henwood Inc. for their candid discussions of noise suppression work undertaken independently by their companies.

The helpful comments and guidance from the Technical Committee of the Canadian Diamond Drilling Association is both acknowledged and appreciated. The special contributions of Messrs. G. Pipher, C. Watson and D. Holland are particularly noted.

ABSTRACT

This report addresses the third stage in a continuing series of studies on diamond drill noise suppression conducted on behalf of, and in cooperation with, the Canadian Diamond Drilling Association (C.D.D.A.). The project is funded by the Canada Centre for Mineral and Energy Technology (CANMET) as part of their ongoing program to support the Canadian Diamond Drilling Industry in problem areas of immediate concern. In brief, the first study examined the general situation with respect to operating noise levels with all classes of diamond drills, and found that virtually all drills exceeded provincial noise regulations currently in force across Canada. The second study quantified some of the principal noise sources on diesel and pneumatically powered drills, and reviewed available noise control equipment, materials and methods which might be appropriate for use on diamond drills. The present study focuses on diesel-powered surface drills, deferring pneumatics until Stage 4, and addresses the technical and economic feasibility of implementing proposed noise controls on the power packs, front ends and heads of the more commonly used surface drills in Canada.

Results of studies on prototype acoustical engine enclosures, alternate gear sets for front ends and heads, and alternate swivel head arrangements are reported, along with updates on earlier surveys within the industry regarding the types of drilling equipment currently used in Canada, and noise control features now commercially available from diamond drill manufacturers.

Information available to date indicates that noise control on surface drills appears to be technically and economically feasible to the 90 - 93 dBA level. Major changes in conventional drill design may be necessary if lower noise emission levels must be achieved. However, the need for such is unlikely since a drill operator's average daily noise level exposure will usually be lower than the instantaneous noise levels quoted above, and should therefore comply with most existing noise regulations.

On the basis of this study, recommendations are made to implement the noise treatments required to achieve the above target. It is also recommended that the focus of future studies be shifted to underground pneumatic diamond drills.

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1. OBJECTIVES

1.1 To establish the technical feasibility of previously-proposed noise treatments for the power pack, front end and head assembly of diesel-powered surface drills.

1.2 To estimate the probable cost of implementing the above, and subsequently examine the economics of proceeding with retrofit noise controls on existing drills or those associated with the replacement of existing equipment with drills of newer and quieter design if the former costs seem unreasonable.

1.3 To define any need for, and direction of, future work on diamond drill noise suppression.

2. SCOPE

2.1 Data from a previous survey of Canadian diamond drill users were updated by CANMET to confirm the types and makes of diamond drills that are most representative of the ones used in Canada.

2.2 Diamond drill and diesel engine manufacturers in Canada, the United States and overseas were surveyed by Noranda Research Centre (principal contractor to CANMET) to see if there had been any recent innovations in noise control which could be purchased as an option with new drills or adapted to existing drills.

2.3 CANMET built and tested a prototype acoustical engine enclosure on a BBS-37 drill equipped with a GM 353 diesel as a means of demonstrating the technical feasibility of silencing drill power packs.

2.4 Noise sources on a Longyear 38 drill were measured under field conditions and rank-ordered by Noranda Research as a check on similar data collected previously on an older model BBS-15.

2.5 Studies of gear sets which might be suitable as quiet-operating options to existing gears in drill front ends and heads, were initiated by Dr. L. T. Russell of the Technical University of Nova Scotia, working in close collaboration with Noranda Research. Alternate swivel head arrangements which would allow the bevel gears in the drill head to always remain in contact were explored, and subsequently discussed with Canadian drill users and manufacturers.

2.6 Noise control options that have been demonstrated on diamond drills to date were reviewed along with attendant costs by Noranda Research in order to identify the most cost-effective manner in which drill owners wanting to implement noise controls could proceed at this time.

3. OBSERVATIONS

3.1 Approximately 74% of the diamond drills used by the Canadian diamond drilling industry are diesel or gas-powered surface drills, and most of these are diesel-powered (69%). Pneumatically-powered underground drills represent most of the balance (24%), with the remainder (2%) being electrically driven underground units.

The most commonly used makes of diesel-powered surface drills are the Dresser-Boyles Model BBS-37 and Longyear Model 38, which are typically equipped with engines in the 60 to 80 HP range and feature mechanical rotation of the drill bit, hydraulic thrust, and a swivel head which hinges at the bevel gears.

3.2 An international survey of diamond drill manufacturers indicated that only one (Sprague & Henwood in the U.S.) actually provides a noise control package for the class of drills described above.

3.3 Most of the major diesel engine manufacturers appear to have some level of noise control activity underway, but only one German manufacturer (Hatz Diesel) is able to claim a noise level of 90 dBA for engines in the 30 to 80 HP range while operating in a normal drill shack environment.

3.4 The technical feasibility of acoustical engine enclosures has been thoroughly demonstrated by CANMET, by at least one engine manufacturer, by at least one drill manufacturer, and by at least one drill user. The latter has also demonstrated cost feasibility under normal market conditions.

3.5 Noise measurements on a recently-purchased Longyear Model 38 drill confirmed the number and importance of noise sources measured previously on an older Model BBS-15 drill. Hence the need for noise controls on each of the power pack, front end and head in order to achieve compliance with noise regulations was also confirmed.

3.6 Preliminary engineering studies have shown that it may be possible to substitute helical gears for existing spur gears in drill front ends, and spiral or hypoid bevel gears for existing straight cut bevel gears in drill heads on a retrofit basis. The latter change would eliminate the popular swivel head feature, however.

At least one U.S. drill manufacturer (Sprague & Henwood Inc.) already offers both options as part of a noise control package. There was no apparent need for a major drill redesign effort in order to implement these changes.

3.7 Preliminary engineering studies have shown that it may be possible to redesign the existing head assembly on drills in a manner which will allow the head to remain permanently closed (and, therefore the use of spiral gears), yet still allow the head to swing away by altering the mechanical linkage to the remainder of the drive train.

Initial discussions with drill manufacturers have indicated these modifications could only be accomplished at considerable cost. Subsequent discussions with drill users have raised questions of whether the swivel head feature is expendable when trying to achieve compliance with provincial noise regulations at a reasonable cost.

3.8 Noise controls that have been demonstrated on various diamond drills to date indicate that an overall noise level of 90 - 93 dBA is probably achievable on the class of drills of interest using retrofit noise control treatments. Elimination of the swivel head is necessary in this case, however. Drill users who are able to install the required treatments themselves should be able to do so at an approximate cost of $8,000, which includes material and labour. Actual costs and difficulties which may be encountered in implementing these treatments on BBS-37 or Longyear 38 drills remain to be determined.

4. CONCLUSIONS

4.1 Since the majority of diamond drills used in Canada are diesel-powered surface drills, efforts to alleviate noise problems associated with this class of drills are well conceived.

4.2 There is ample room in the market for drill manufacturers wanting to take a lead position in providing noise control options for their equipment.

4.3 Diesel engine noise emissions will gradually decrease over the long term. At this time, however, only the Hatz diesels can comply with provincial noise regulations; they will probably retain that distinction over the near term.

4.4 Acoustical engine enclosures are now a proven noise control method for diamond drills, and any provincial authority could reasonably request that a user install such a device as part of a noise compliance plan.

4.5 Recent noise data confirm the need to treat engine, front end and head noise in order to achieve compliance with provincial regulations.

4.6 It should be possible to install quieter-operating gear sets in existing drills without the need for major design changes in existing gear housings.

4.7 The need to retain the swivel head feature on "quiet" drills should be seriously re-examined by drill users, since the implications of doing so are significant from a cost point of view.

4.8 Under routine drilling conditions, rigs emitting nominal noise levels of 90 - 93 dBA should still be able to comply with provincial noise regulations because the average daily noise exposure of an operator is typically lower than the noise level emitted by the equipment due to the normal rest periods, intermittent shutdowns, etc. encountered during a regular working day. Exceptions can occur when the normal working shift is extended, or during particularly intensive production periods.

5. RECOMMENDATIONS

5.1 Some unfinished work on engine enclosures and gears should be carried out (as described below) in order to properly complete the studies on the surface class of drills. However, the thrust of continuing studies on diamond drills should now be shifted to pneumatic drills, where a systematic examination of the relevant noise sources and appropriate noise treatments should be undertaken.

5.2 Diamond drill manufacturers operating in Canada should consider making noise control options available to future buyers so that the need for retrofit noise controls can be eliminated. Meanwhile, Canadian drill users in the market for a new drill have the option of buying drills equipped with a noise control package from abroad.

5.3 By late 1983, "quiet" diesel engines over the full range of 30 to 80 HP should be available from at least one supplier. Drill manufacturers should offer these engines as an option on new drills. Users having to replace an engine should consider purchasing a "silenced" engine at the outset and thereby avoid retrofit costs and problems at a later date.

5.4 Drill users facing the prospect of having to silence existing engines should consider fabricating their own enclosures using the guidelines described later in this report and some supervisory acoustical engineering assistance to ensure that adaptations of the enclosure are in fact installed properly.

A joint demonstration project between an interested user and the Federal Government project-contractor might be the best way of identifying potential problem areas inherent in this approach, and ways of dealing with them for the benefit of subsequent users.

5.5 The possibility of using helical and spiral gears to treat existing gear noise problems should be examined further.

5.6 An interested drill user should consider carrying out a joint study with the Federal Government project-contractors to determine if simple gear substitutions can be made in the front end and head, and to measure the effects of making these changes.

5.7 Consideration should be given to abandoning the swivel head feature in favour of some other appropriate solution (such as retractable drills).

5.8 Drill users should start to phase in retrofit noise controls on existing equipment as soon as possible and as quickly as resources permit. New equipment should be purchased with noise controls already installed in order to avoid problems and retrofit costs at a later date.

6. INTRODUCTION

Earlier studies on diesel-powered surface drills had shown that several major drill components, namely the power pack, front end, and head (also the water pump when powered by a separate diesel engine), were collectively responsible for overall noise levels of 100-107 dBA observed on rigs operating under normal drilling conditions. Moreover, it was shown that all of the major noise components would have to be treated if compliance with existing provincial noise regulations is to be achieved. Suggestions for treating each individual noise source were made, but remained to be technically proven[1,2].

The thrust of this study was directed at demonstrating the technical feasibility of acoustical engine enclosures, identifying, in cooperation with Canadian drill manufacturers, suitable noise-reducing design changes for both the front ends and heads, and examining the cost/benefit aspects of retrofitting existing drills with the above modifications. Although the demonstration work did not proceed as far as originally planned, contact with a U.S. diamond drill manufacturer who had already implemented most of the modifications being considered enabled most of the study's goals to be achieved. Various activities carried out over the course of 1982 in connection with the above goals are summarized herein, together with suggested noise control actions.

7. UPDATE OF DRILL USE SURVEY

As a check on the type of drilling rig/power pack combinations which best represent the ones currently used in Canada, CANMET re-examined and updated the results of an equipment survey undertaken at the outset of the diamond drill noise suppression studies[1]. A total of 21 firms had responded to the survey, representing the Atlantic Provinces (3), Québec (7), Ontario (5), Manitoba (1), British Columbia (4), and the Yukon (1). The reported numbers and makes of drills in use in 1980 are summarized in Table 1[3]. It is evident that Boyles and Longyear drills are currently the most commonly used models.

TABLE 1 - NUMBERS & MAKES OF SURFACE DRILLS IN USE IN CANADA DURING 1980

	MAKES	NO.	% OF TOTAL
1.	Boyles	243	49
2.	Longyear	163	33
3.	J. K. Smit	16	3
4.	Wesdrill	3	<1
5.	Inspiration	20	4
6.	Acker	9	2
7.	Heath and Sherwood	15	3
8.	Chicago Pneumatic	3	<1
9.	Atlas Copco	4	<1
10.	St. Lambert Drilling Ltd.	8	2
11.	Morissette	1	<1
12.	Joy	1	<1
13.	Homemade	6	<1
		492	100

Table 2 ([3]) summarizes the models within the Boyles and Longyear makes in use at the time of survey.

TABLE 2 - DRILL MODELS MOST COMMONLY USED IN CANADA IN 1980

BOYLES MODELS			LONGYEAR MODELS		
Model No.	No. of Units	% of Total	Model No.	No. of Units	% of Total
1 or 15	36	15	24	4	2
17 or 25	103	42	34	1	1
35 or 37	72	30	38	103	63
45 or 56	30	12	44	48	30
3 or 70	2	1	HC-150	5	3
			Hydra Core 28	2	1
	243	100		163	100

Inspection of Table 2 indicates that the Boyles Models 25 and 37 and Longyear Models 38 and 44 drills are most representative of the class of drills currently used for surface drilling in Canada. Accordingly, noise control studies were

focused on this class of drills as recommended by the Technical Committee of the Canadian Diamond Drilling Association.

These drills can be generally characterized as having a mechanical gear train to provide drill rotation (including straight cut bevel gears mounted inside a swivel head), and dual hydraulic cylinders to provide drill feed (i.e. bit thrust) Most drills (95.5%) are powered by diesel engines (versus 2.5% gasoline and 2% electric), and of these, 43% were built by GM, 28% by Ford, 16% by Deutz, 8% by Hatz, and the remainder by Perkins, Caterpillar and others.

8. INTERNATIONAL SURVEY OF DIAMOND DRILL MANUFACTURERS

To insure an awareness of noise suppression activities on an international scale, a survey of drill manufacturers in Canada, the United States and Europe was carried out. Manufacturers, selected from the 1981 Manufacturers' Directory of World Mining Journal, were asked to comment on noise controls already implemented or planned on their diesel power pack, the power train, and/or head. Noise level measurements, equipment pictures, sketches, etc. were also requested where available. A sample letter and a table summarizing who was contacted as well as the essence of the replies obtained is included in Appendix A.

In summary, 13 out of 24 companies contacted eventually responded. Of these, six claim to offer noise-reducing options on their machines. Three manufacturers from this category are located in the United States, one in Canada, one in Sweden, and one in England. The above distribution approximately reflects where noise regulations are most vigorously enforced. It is worthy of note that another British firm is currently examining the prospect of supplying a sound-proofed power pack with their drills, and that the British Drilling Association will include noise as one of several factors to be included in a proposed "Drill Rig Rating". In fact, the author's survey letter was instrumental in reminding the Association of an omission in their recommended specifications; they expressed interest in the work going on in Canada([4-10]). Perhaps the above findings are an indication that Canada could establish a lead position in this field.

Regarding the types of noise controls implemented to date, one of the American companies, Sprague & Henwood Inc., appears to have been the most progressive manufacturer, offering drills with modifications to their standard power pack, front end and head. Details are described later in Sections 9.3 and 10.3, but in brief involve soundproofing of the power pack, use of "quiet-operating" gears in the front end, and spiral bevel gears in the head - the same basic design changes which were being sought on

Canadian drills. Overall noise levels in the operator's position of 94.5 dBA were reported with this configuration (and confirmed by personal measurements). A further noise reduction to 90 dBA was reported when acoustical panels were extended beyond the engine enclosure up to and including the front end. However, the latter modifications were not found to be acceptable in practice([11]).

Two of the remaining five manufacturers claiming the availability of noise control options offer sound-proofed power packs, and the last three claim reduced noise levels on their drills through the use of helical and spiral cut or unspecified gears at various points in the power trains. The latter claims remain to be substantiated by actual noise level measurements.

An observation which emerges from this survey is that a surface type diamond drill which emits 90 dBA or less (in the operator's position) does not yet appear to be commercially available.

9. POWER PACK CONSIDERATIONS

A three-pronged approach was used in studying possible methods of reducing power pack noise levels. The first consisted of a brief survey of the major diesel engine suppliers to see if any major new developments could be expected in the near future. The second took the form of a demonstration project by CANMET which was intended to show the magnitude of engine noise reduction possible by use of a properly constructed acoustical engine enclosure. The third was to monitor work already underway by the previously-mentioned American firm, Sprague & Henwood Inc., and a Canadian firm, St. Lambert Drilling Ltd. of Valleyfield, (Québec) who was introducing radically new design concepts on a hydraulic drill and drill shack.

The outcome of each study is reported in detail below.

9.1 Survey of Diesel Engine Manufacturers

A brief check of the literature indicates that research on the noise characteristics of internal combustion (IC) engines is being actively pursued in the United States and overseas. In one issue of one journal alone, eight references were found to textbooks and recent papers concerning noise control methods for IC engines including the effects of fuel on diesel engine noise, relationships between cylinder pressure or piston slap and diesel engine noise, the effects of engine block structural design on noise radiation, etc.([12]). Unfortunately, none of the work monitored to date appears to suggest that placement on the

market of a diesel engine which will operate at noise levels of 90 dBA or less without the aid of acoustical panels is imminent. Nonetheless, great strides are being taken by some manufacturers to reduce noise emissions from their engines in comparison to older models. These efforts are worth noting, especially in the context of new equipment purchases or engine replacements, and engine manufacturers responsible for spearheading this work should be encouraged to continue.

The four principal manufacturers of diesel engines for diamond drills (i.e. GM, Ford, Deutz and Hatz) were contacted to see if any prospect of a "quiet" engine was in the offing. A sample letter to the manufacturers and the replies received are included in Appendix B.

In brief, GM, Ford and Hatz responded. GM included data for their 3, 4 and 6 cylinder 53T series engines showing noise levels of 93, 97 and 96 dBA, respectively, as measured at 1m and 2500 rpm. Ford (England) indicated that a new series of diesel engines (i.e. their 2720 Range) has recently been introduced to replace the older 2710 series, with "significantly reduced noise emissions". Although no specific noise data were reported, it was claimed that a four cylinder model in the new series (i.e. 2722) would emit noise in the low 90 dBA range when measured at three meters. Hatz have added the L40 series of engines to their previous L30 "Silent Power System" to provide power packs ranging from 20 to 80 HP. The L40 engines are claimed to generate approximately the same noise levels as the L30 engines. One of these (a 3L30) was measured by Noranda Research Centre at 90 dBA in the drill operator's position while driving a BBS-15 on site at the Northern College of Applied Arts and Technology([2]). Readers not familiar with the Hatz line of engines should realize that the engines come equipped with a very compact acoustical engine enclosure (see Appendix B).

As previously mentioned, the above results are very encouraging; however, the continuing need for acoustical engine enclosures is readily apparent.

Two other interesting developments with respect to diesel engine noise are: (i) the recent announcement by Perkins Engines of Peterborough, England, of a turbocharged four cylinder engine (Model T4236, up to 76 KW) which, among other features, also claims to operate at reduced noise levels([13]), and (ii) a practice adopted by drill manufacturers Sprague & Henwood Inc. of modifying a standard semi-enclosed engine by John Deere to produce a functional acoustical engine enclosure. The latter is described in more detail in Section 9.3.

9.2 Prototype Engine Enclosure by CANMET

Quite apart from the question of whether 'quiet' engines have become available for new drills is the problem of having to retrofit engines with noise controls on existing drills. Although the use of acoustical engine enclosures has become commonplace on certain types of equipment like air compressors, several open questions remained as to whether these enclosures could be adapted to diamond drill rigs:

(i) without major modification to existing support structures (e.g. skids, couplings);

(ii) without unacceptably hampering engine access for routine inspection and servicing;

(iii) without adding excessively to existing rig weight (an important factor where rigs have to be flown into the drill site via helicopter);

(iv) without incurring prohibitive costs.

CANMET undertook to build and test a prototype acoustical engine enclosure as a means of shedding light on some of these questions.

Thanks to Midwest Drilling Co. of Winnipeg, CANMET obtained a BBS-37 drill (powered by GM 353 diesel) on loan for the purpose of this demonstration project. It is evident from Section 7 that this drill is fully representative of the class of surface drills most commonly used in Canada. The drill was shipped to Ottawa for fitting of a noise enclosure around its engine in the CANMET shops, and for acoustical performance testing at the CANMET laboratories.

The appearance of the drill before and after fitting of the engine enclosure is shown in Figures 1A and 1B. A general arrangement drawing of the enclosure itself is shown in Figure 2. Salient features worth noting include the labyrinth cooling air and combustion air intakes, warm air exhausts, the engine exhaust muffler, the close-fitting drive shaft exit hole from the enclosure, and the vibration isolation pads inserted between the original skid and diesel engine. The acoustical enclosure panels are a sandwich construction consisting of a 16 ga. steel exterior, a 1 in. fibreglass middle and an expanded metal interior which both protects the fibreglass and holds it in place.

As shown, the enclosure was capable of reducing noise levels in the operator's position from approximately 100* to 80 dBA when the engine was operated alone with the throttle wide open([3,14]). The 20 dB reduction obtained compares very favourably with the 15-20 dB design goal selected earlier in the program. Additional tests under simulated load conditions achieved by coupling the engine

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* corrected for reverberation effects

Fig. 1 - BBS-37 DRILL WITH GM353 DIESEL

Fig. 1A - Drill In Canmet Shop During Construction of Engine Enclosure

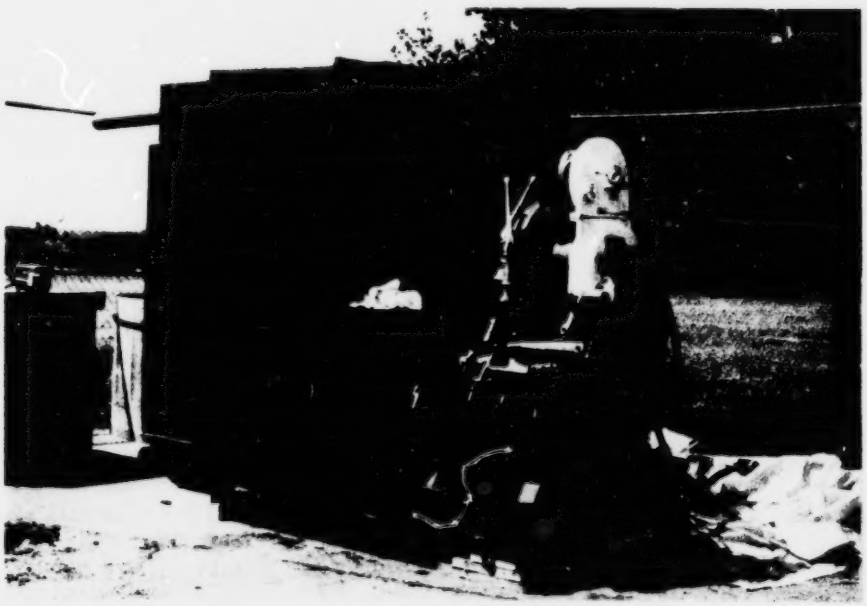

Fig. 1B - Drill with Engine Enclosure Installed

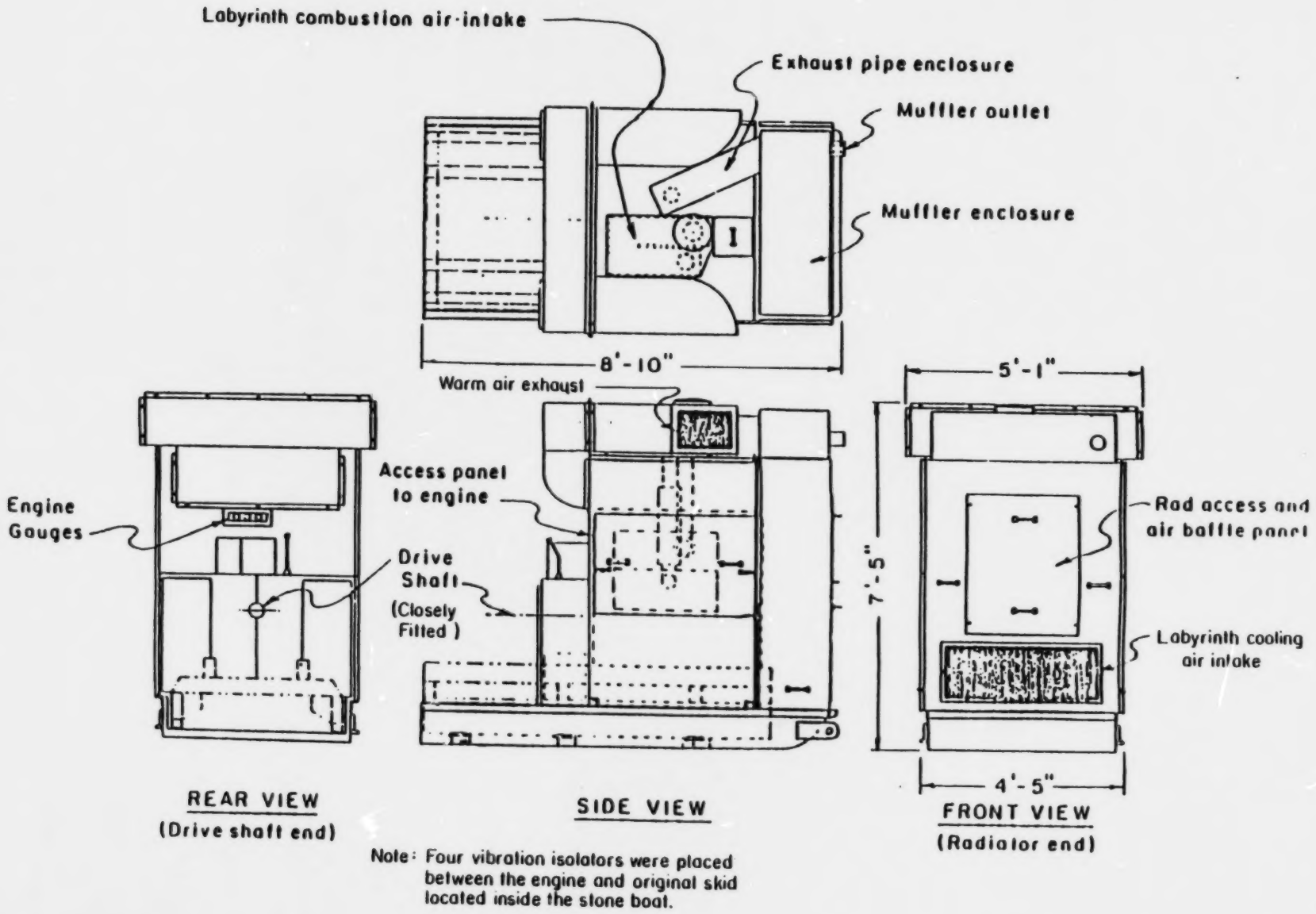

Fig. 2 - General Arrangement of Diamond Drill Diesel Engine Sound Enclosure

directly to a dynamometer showed that engine noise levels increase significantly with rpm (typically upwards of 10 dB between idle and full rpm), yet are virtually independent of load. This result is consistent with findings of other researchers[12].

A few difficulties were encountered during the fabrication and testing phases which are worth noting. Because the drill was on loan, all modifications had to be implemented in such a way as to cause minimal disturbance to the original drill configuration. Hence, use of the "stone boat" construction under the original skids and the large bulky panels around the perimeter of all engine surfaces. This resulted in a much heavier and more voluminous construction than was desirable, complicated fitting and sealing around the drive shaft, and ultimately resulted in a diesel fuel overheating problem since the fuel tank remained inside the acoustical enclosure. Normally, an engine enclosure would be much closer fitting and lighter (e.g. Hatz diesel cowlings), would therefore avoid most of the above problems, and would be much easier to fabricate. Hence, although the prototype enclosure amply demonstrated what was technically achievable in terms of engine noise reduction, the enclosure configuration employed (including access panels, etc.), and material and labour costs associated with its construction are somewhat unrepresentative (costs and weight on the high side). A preliminary design which is thought to be more suitable for field use is discussed later in Section 11.

Appendix C contains additional details regarding the prototype enclosure construction and pictures illustrating various stages of construction.

9.3 Engine Enclosure Options From Sprague & Henwood Inc.

The Sprague & Henwood Inc. equivalent of a BBS-37 or Longyear 38 is a Model 142C. It comes equipped with a four-cylinder, water-cooled John Deere diesel engine with comparable horsepower and rpm to the GM 353 (i.e. 63 versus 64 HP at 2200 rpm), and also features mechanical rotation and hydraulic thrust.

Two approaches to engine noise control have been used by Sprague & Henwood Inc. to date which are identical in principle, but quite different in practice. The first is illustrated by Figures 3 and 4, and represents their "partially enclosed" unit. Focusing on the engine portion of the rig only for the moment, Figure 3 shows the standard John Deere engine enclosure, to which is added a 1 in. lining of soundfoam on the two interior surfaces of the side and end visible in Figure 3. Immediately on top of the engine enclosure are the engine exhaust muffler (vertical cylinder) and combustion air intake silencer (horizontal cylinder just behind exhaust muffler). Immediately beneath the engine enclosure are two panels mounted on the drill skids (one is only partially visible in Figure 3, more obvious in Figure 4). These panels act as noise barriers and deflect noise from the bottom of the engine enclosure (which is open) away from the operator. The panels are fabricated out

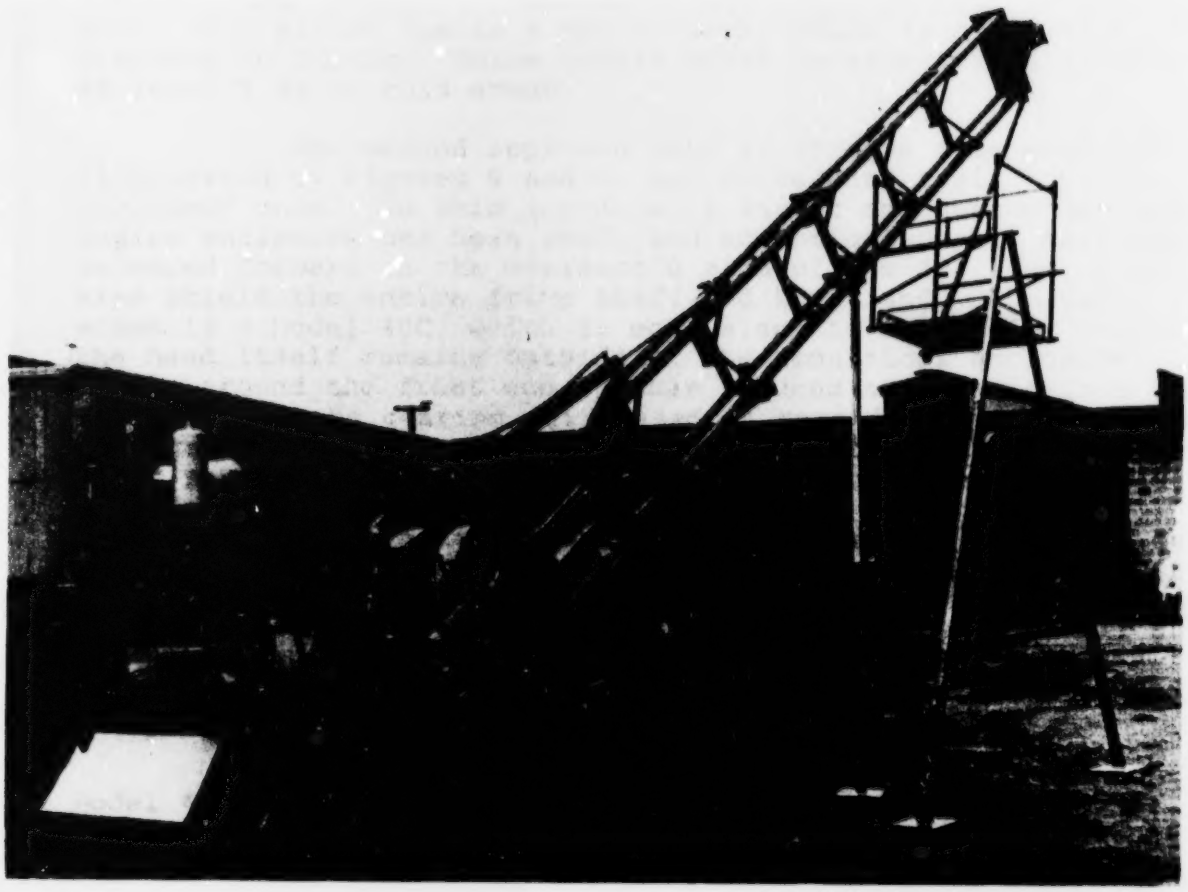

Fig. 3 - Sprague & Henwood Inc. Model 142C Drill (Front End View)

Note The Hydraulically-Operated Derrick which compensates for drill offset when the drill is retracted.

Fig. 4 - Sprague & Henwood Inc. Model 142 C
Drill (Back End View)

of noise dampened steel in order to prevent them from acting as noise radiators as a result of structureborne vibrations. The treated engine operating outdoors by itself at 1800 rpm (i. e. the normal recommended speed) was found to emit 82 dBA when measured in the operator's position([11]). This compares very favourably with the 80 dBA level observed in the case of the CANMET prototype. It should be noted, however, that the noise deflection panels located beneath the engine take advantage of air absorption to limit noise levels ultimately reaching the operator. This advantage would be lost if the drill were placed inside a drill shack, which is a common practice in Canada. Noise levels could be expected to rise by at least 5 dB in this event.

The second approach used by Sprague & Henwood is illustrated by Figures 5 and 6, and represents their "fully enclosed" unit. In this instance, a larger and custom-designed engine enclosure has been used, and acoustical panels have been extended forward on the operator's side of the drill so as to also shield the entire drive shaft and front end. The unit shown is a Model 40C, which is equivalent to a BBS-15. Only the head itself remains outside of the acoustical enclosure. Panels around the front end further reduced noise emissions from some of the gearing (discussed in more detail later). This arrangement, however, was not found to be practicable by operators after several months of operation because the extended panels hampered access to certain drill components during routine maintenance. The panels were eventually removed. Although quite independently designed, the engine enclosure itself bears a striking resemblance to the CANMET prototype, and incorporates the same basic features (i.e. acoustical absorption inside, combustion air and engine exhaust silencers, access panels, etc.). Note that a hydraulic pump which is mounted just below the radiator has also been built into an enclosure.

To date, Sprague & Henwood have manufactured one Model 40C drill, and two Model 142C units. The latter style appears to be most readily accepted by users, and also features a modified gear train as discussed later in Section 10.3.

9.4 Recent Improvements Achieved by St. Lambert Drilling Co. Ltd.

A Canadian drill contractor in Valleyfield, Québec, who also builds his own drills has recently implemented some advanced noise control design concepts for hydraulic drill rigs which were thought to be worthwhile reporting here, even though the class of drill concerned is different from that discussed so far. In this instance, the drill is completely hydraulic (i.e. hydraulic rotation, thrust and chuck), and is housed in a

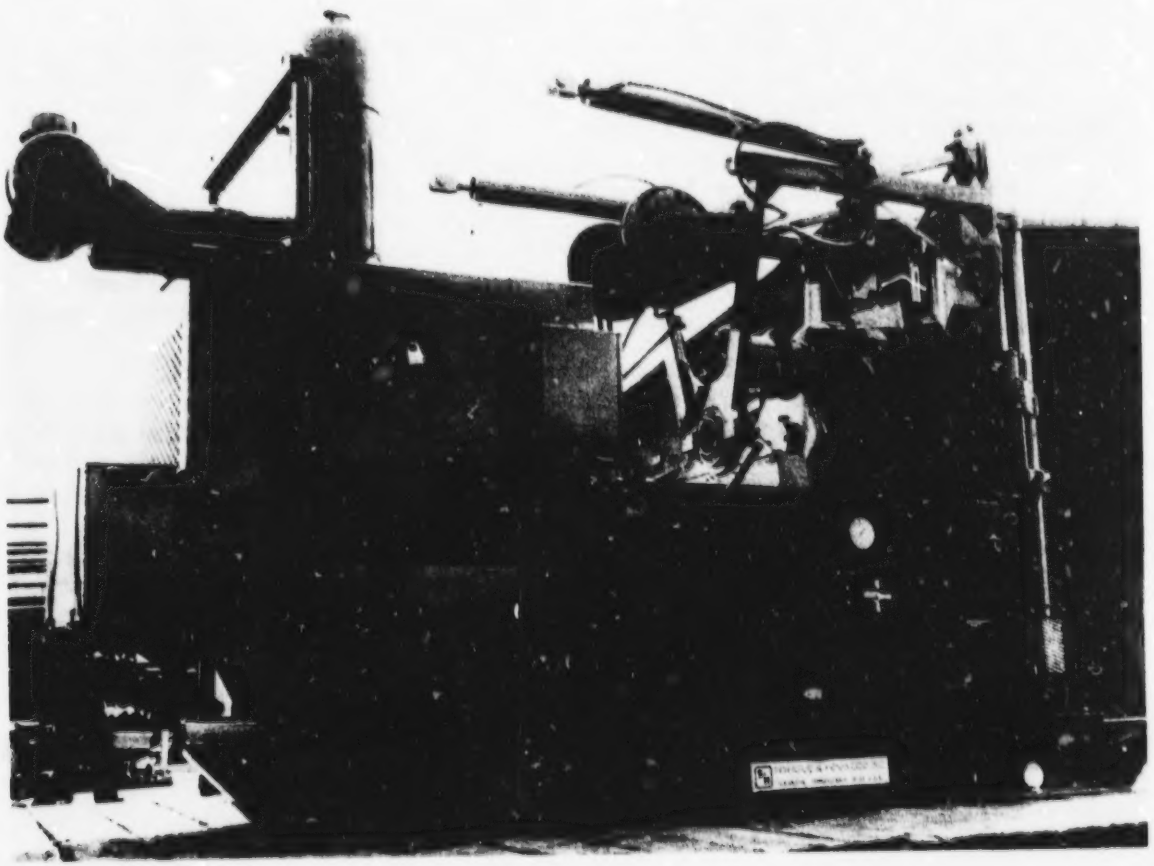

Fig. 5 - Sprague & Henwood Inc. Model 40 C
Drill (Side View)

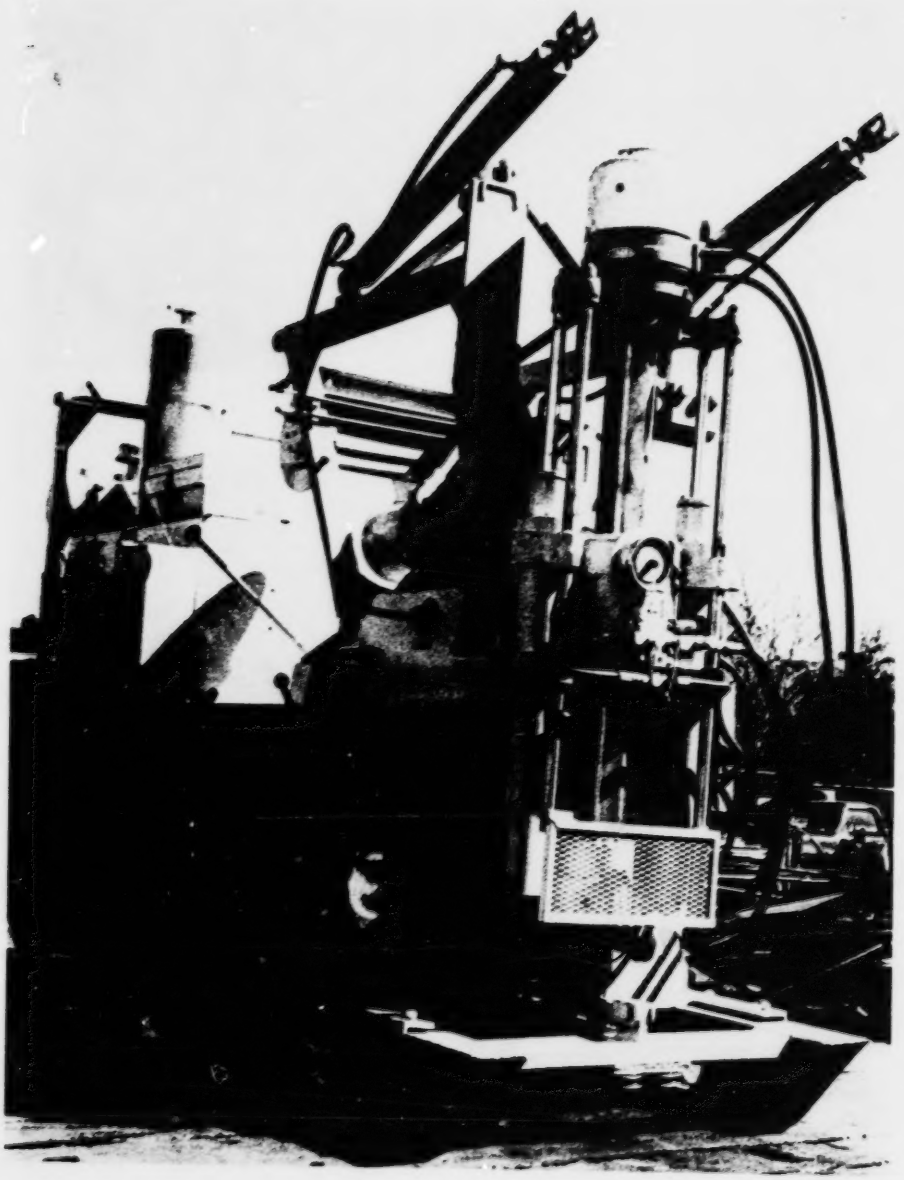

Fig. 6 - Sprague & Henwood Inc. Model 40 C
Drill (Front End View)

permanent drill shack as opposed to the disassembling type more typically found in Canada. Two models have been built to date, the SRS-900-1, which is powered by a five-cylinder air-cooled Deutz diesel, and the COPCO 251-1, which is powered by a four-cylinder Deutz. Apart from the difference in power packs, the COPCO 251-1, which is the latest of the two models, was equipped with a different clutch and a newer hydraulic head which is said to contain higher precision gears. Otherwise, the drills and shacks are virtually identical.

The overall layout of the shack and drill are illustrated in Figures 7 and 8. Note the outside access door to the engine compartment in Figure 7B which facilitates routine inspections. In Figure 8A is seen the acoustical engine compartment (lower right hand corner) and the perforated steel panels of the sound absorbent walls (2 in. thick fibreglass). Combustion air is ducted in from the rear wall of the shack, and cooling air is available through a grill in the rear wall. Heated air from the engine is directed into the cavity under a false floor, and filters up between the planking in the floor to heat the drill shack. Figure 8B shows the quiet-operating, hydraulically-powered water pump (Brama Model 24). Another noise control feature which was used but is not readily apparent from the above pictures was to restrict most of the high pressure hydraulic hose runs to the cavity under the false floor. With the exception of hoses going to the head assembly, all hoses above the floor (i.e. to the operator's controls, etc.) are low-pressure hoses.

With the configuration described above, the SRS-900-1 was found to run at 95-98 dBA in the operator's position depending on the elevation of the head on the drill boom, and the COPCO-251-1 was found to run at 92 dBA*. Additional measurements under the same conditions showed that the acoustical engine enclosure limited noise levels from either engine to approximately 82 dBA when operated in neutral and at 2350 rpm (maximum rpm for both engines). This figure is comparable to CANMET and Sprague & Henwood results. When the water pump was engaged, noise levels rose to 83-84 dBA on both models, and finally, the above quoted levels in excess of 90 dBA were observed when the head was engaged to commence normal drilling([15]). The improved gearing in the head of the COPCO-251-1 model appears to have been responsible for a noise reduction of 3 to 6 dBA observed in these measurements.

Subsequent measurements on the SRS-900-1 drill after approximately a year's operation in the field indicated that the noise control package had stood up very well, and that noise levels remained unchanged from when the drill was new. Noise

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* Drill shack roof panels and ventilation panel (on rear wall) were open during measurements. Shack door was closed. Both drills were new.

Fig. 7 - OUTSIDE VIEWS OF ST. LAMBERT DRILLING CO. LTD. MODEL SRS-900-1 DRILL SHACK

Fig. 7A - Typical Set-Up on Drill Site

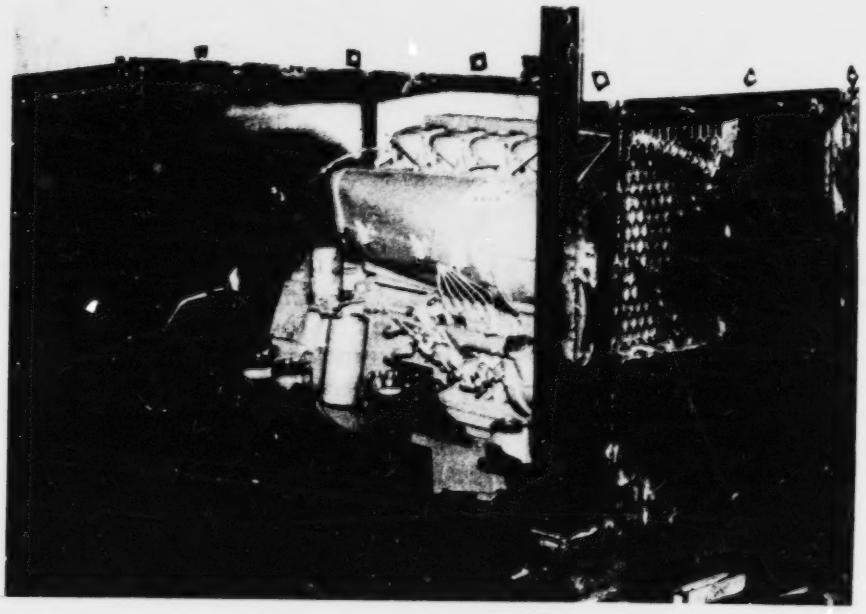

Fig. 7B - Outside Access Door to the Engine Compartment (Shack still under construction. Note cooling air intake & acoustically-lined engine compartment.)

Fig. 8 - INSIDE VIEWS OF ST. LAMBERT DRILLING CO. LTD. MODEL SRS-900-1 DRILL SHACK WHILE UNDER CONSTRUCTION

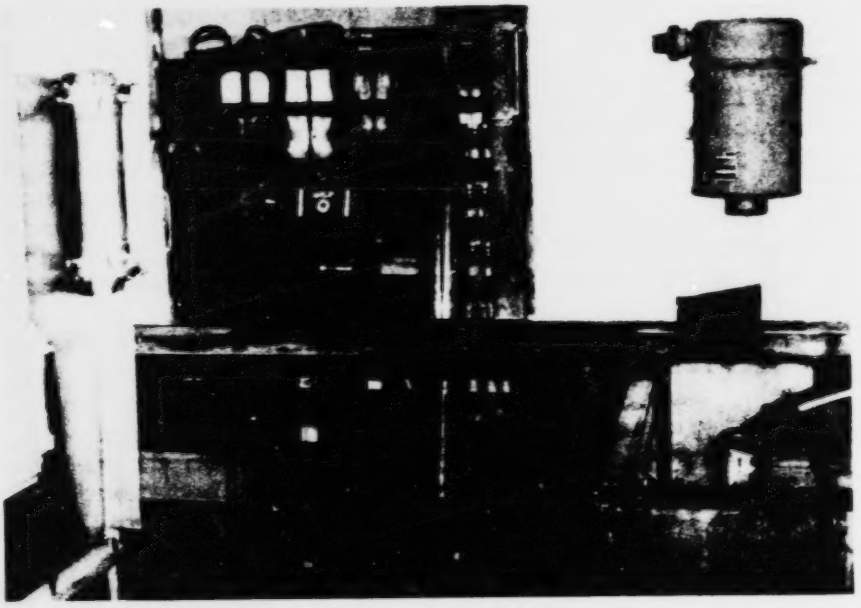

Fig. 8A - Views of Acoustical Engine Compartment (Lower Right Hand Corner) and Perforated Steel Panels of Sound Absorbent Wall

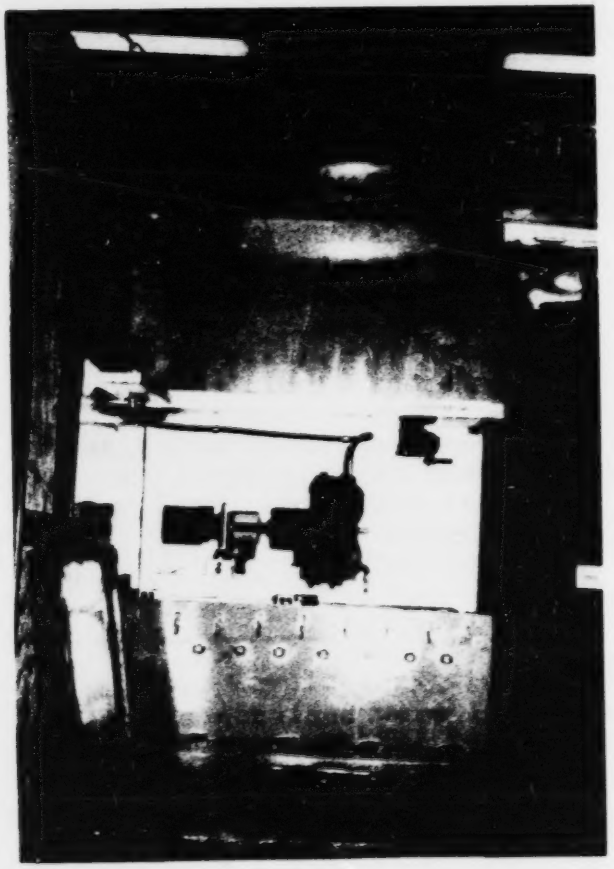

Fig. 8B - Quiet-Operating Water Pump

dosimetry on the drill operator indicated a typical average noise level (i.e. equivalent noise level, or Leq) while operating this drill on a routine day would be 94 dBA([16]). This figure is lower than the 95-98 dBA level quoted above because it takes quiet periods which may occur over the normal working day into account. The implication of this average noise level is that an operator could be legally exposed to the drill noise without hearing protection for 4.7 hours daily instead of 2.7 hours as implied by the previous spot measurements. Of course, if hearing protection is worn, exposure time can be greatly extended, but is dependent on the wearing habits of the operator, and the efficiency of the hearing protectors used([17]). It is worth noting here that the use of hearing protectors is not accepted by the authorities as a suitable long term noise control solution.

10. GEAR CONSIDERATIONS

10.1 Field Measurements on a Longyear 38

Previous noise measurements in the operator's position of a BBS-15 had shown that the principal noise sources were as summarized below in Table 3([2]).

TABLE 3 - PRINCIPAL SOURCES OF NOISE MEASURED ON A BBS-15

(ref. the operator's position)

	Drill Rig Component	Type	dBA
1.	Power Pack	Deutz, 2 Cylinder (26KW/35HP) Air-Cooled, with Muffler	98
2.	Head Gear	Straight Cut Bevel	97
3.	Water Pump	Diesel-Powered	96.5
4.	Front End	Open Chain-Driven	95
		Overall	103

Discussion of these data with members of the Canadian Diamond Drilling Association Technical Committee raised some questions of whether the values shown for the head gear and front end were still valid since improvements had been made on newer models of the drill type used during the study.

The question of how accurately the initial set of data represented the noise characteristics of newer drilling rigs arose again in May, 1982, while meeting with a drilling contractor to obtain a user's impression of some preliminary thoughts on possible design changes to existing swivel heads. The contractor

had a Longyear 38 rig sitting in the yard, and graciously consented to starting it up so that the author could listen for any noticeable differences between it and the older BBS-15. A subjective impression of the principal noise sources heard, in order of their importance, was the engine, front end, and head gears. The water pump was hydraulically powered in this instance, and was not audible in the presence of the remaining noise sources. Spot checks with a noise meter indicated that the overall level in the operator's position was 102-103 dBA. The relative importance of the noise sources was as follows: the engine first, the front end second, and the head gear third.* The fact that the front end was noticeably louder than the head gears was surprising, and indicated a need to carry out further measurements in order to determine if design changes being contemplated for the swivel head were indeed necessary.

A new study was carried out in September 1982, on a fairly new Longyear 38 operating near Pugwash, Nova Scotia. The rig is owned and operated by Mr. C. Smith, a sub-contractor to Logan Drilling Ltd. of Musquodoboit, Nova Scotia. The drill was approximately 1½ years old at that time, contained all its original parts, and appeared to be in excellent mechanical condition. It was powered by a four-cylinder Deutz air-cooled diesel (68 HP), which was equipped with an exhaust muffler and exhaust hose for routing fumes out of the drill shack. The shack was an 11 ft x 16 ft x 6 ft plywood construction with a roof that was mainly open, except for an approximately 2 ft wide "L"-shaped strip over the operator's normal work area, and a back wall that was open from roof height down approximately 2 ft along the entire length of the drill (see Fig. 9A). Size BQ rod (16 ft lengths) was in use, and hole depth was approximately 200 ft during the noise tests.

On-site noise measurements were carried out under normal drilling conditions using a GENRAD Model 1933 Precision Sound Level Meter and Analyzer equipped with a ½ in. electret condenser microphone with windscreen. Measurements were typically carried out near the engine (2 ft from engine in available space between engine and drill shack wall), at the drill controls (hereafter called the operator's position), and at a small bench in one corner of the drill shack where the operator occasionally rested when the drill was operating smoothly, and where noise levels were observed to be 2-3 dBA lower than at the controls. Noise levels obtained under most test conditions were also recorded on a Nagra Model SN tape recorder for subsequent analysis on a Nicolet Model 446B Real Time Spectrum Analyzer (RTA). The

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*Determined by measuring noise levels very close to each source (i.e. within 2 in.). Levels obtained were 110, 108 and 104 dBA for the engine, front end and head gears, respectively[18].

Fig. 9 - LONGYEAR 38 DRILL ON WHICH NOISE SOURCE RANK-ORDERING MEASUREMENTS WERE DONE

Fig. 9A - General View of Drill & Site

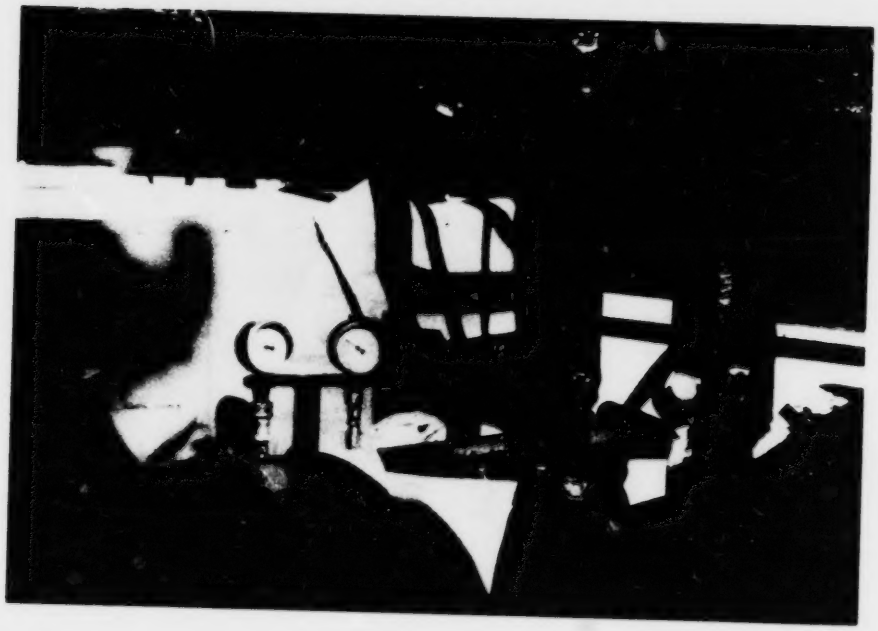


Fig. 9B - View of Temporary Engine Enclosure Used During Measurements

latter data were found to be the most meaningful, and are therefore discussed further below. A limited amount of dosimetry was also carried out during the two days on site, using Metrosonics Type db-301 Profiling Dosimeters.

Narrow band (i.e. 400 line) noise spectra corresponding to three different modes of operation are shown in Figure 10. The three operating modes represented correspond to:

(i) Operating the semi-enclosed power pack at wide open throttle by itself (i.e. automotive transmission was in neutral). A crude acoustical engine enclosure was installed in the field (see Fig. 9B) in an attempt to suppress engine noise sufficiently to allow noise from other suspected sources to be measured directly. A 4 to 5 dBA reduction was obtained in the process, and corresponding engine data are labelled "isolated".

(ii) Operating the engine as before, but with the automotive transmission in fourth gear, and the head gear in neutral. Resulting noise levels should therefore represent the combined effects of the engine and front end.

(iii) Operating the engine and front end as before, but also engaging the head in high gear. Resulting noise levels should represent normal drilling conditions.

The ordinate of Figure 10 shows the noise levels observed for each case in dBA, and the abscissa shows the frequency content of each spectrum over the range 0 to 10,000 Hz. The A-weighting and frequency span applied to each spectrum approximate the response of the human ear, and are useful in helping identify which portion(s) of each spectrum is most offensive. The narrow band resolution helps identify which mechanical components of the system are responsible for the observed noise levels. It should be noted that the dBA noise level with which most readers are probably familiar in the assessment of noise problems is approximately the integrated value or summation of levels over the entire frequency range shown in Figure 10.

Inspection of Figure 10 from the bottom up shows that the effects of the front end and head are clearly discernible even in the presence of engine noise. The most obvious effects can be seen as the rise of a major peak at 4800 Hz when the front end was engaged (middle spectrum), and peaks at 2400, 6300 and 7700 Hz when the head was subsequently engaged (top spectrum). The net contributions of either the head or front end to the total noise energy are obtained by subtracting the engine component from each. This can be done electronically on most RTA's, and in this instance, yielded the results summarized in Table 4([19]).

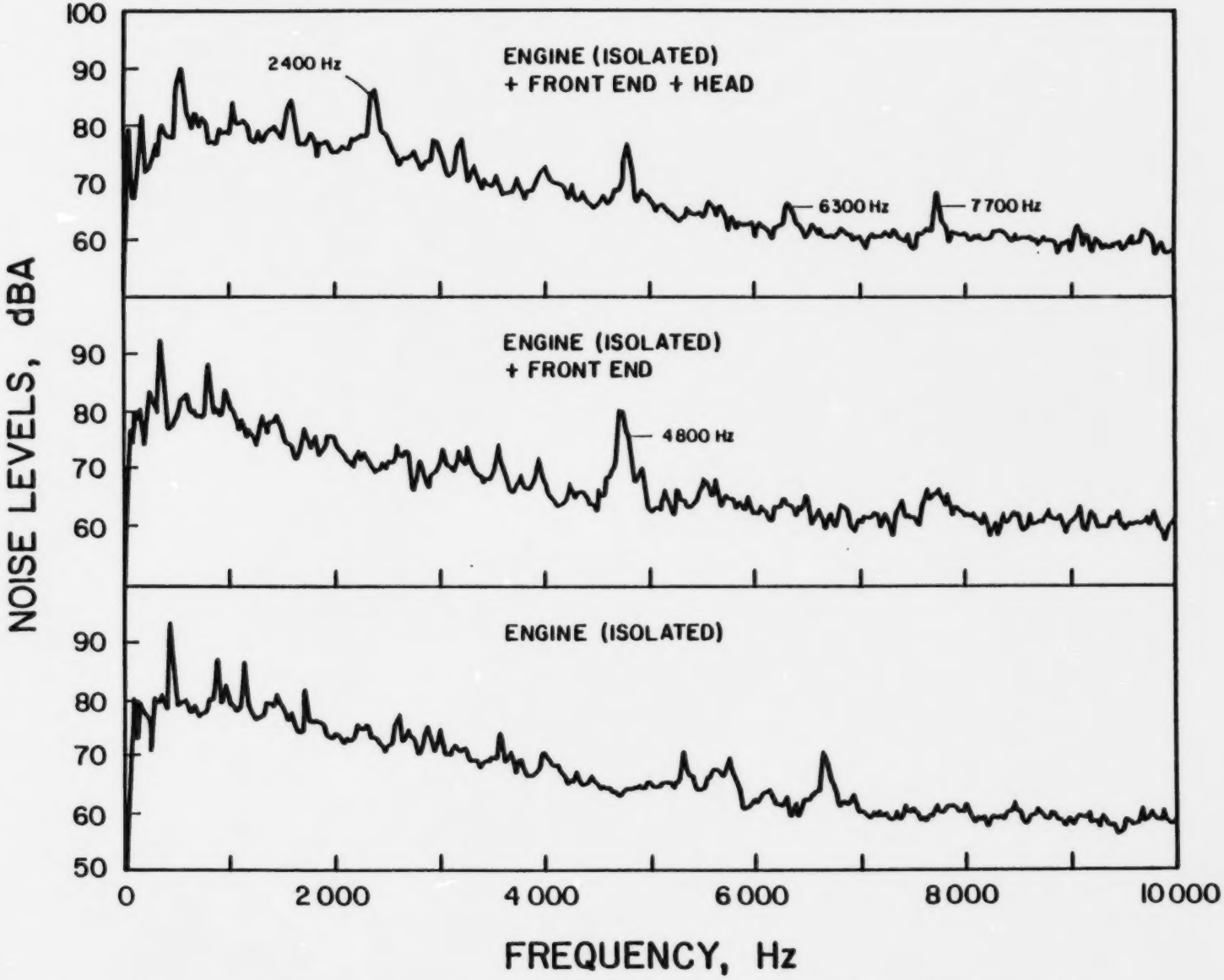


Fig. 10 - Longyear 38 Noise Spectra Corresponding to Several Operating Modes

TABLE 4 - RANK ORDERING OF KEY NOISE SOURCES ON A LONGYEAR 38

(ref. the operator's position)

	Drill Rig Component	Type	dBA
1.	Power Pack[1.]	Deutz, 4 Cylinder (68HP/51KW) Air-Cooled, with Muffler	100
2.	Head Gear	Straight Cut Bevel	97
3.	Front End	Gear-Driven (Spur Gears)	91
		TOTAL	102

[1.] Included in the power pack noise emissions is a component from an auxiliary hydraulic pump mounted at the fan end of the engine which is used to power the water pump. Based on some incomplete test results, emissions from the auxiliary pump are suspected of being at about the same level as the power pack itself.

Comparison of Tables 3 and 4 shows that the older BBS-15 and newer Longyear 38 are very similar in terms of noise output. The gear-driven front end on the latter appears to be an improvement over the chain drive, but it still exceeds regulatory noise levels. Hence the need for continuing noise suppression work on front ends and heads is substantiated. Table 4 also confirms that a well-maintained front end should operate more quietly than the adjacent head. Evidence to the contrary encountered prior to this study is attributed to worn or poorly-lubricated gears in the front end.

Dosimetry measurements on the above Longyear 38 indicated that the typical cycle time required to drill a 16 ft length, exchange the inner tubes and start drilling again was 19 minutes.* Of this, the drill operated at wide open throttle (102 dBA) for 16 minutes, and idled at 90 dBA while exchanging inner tubes, etc. for 3 minutes. The average noise level (Leq) per cycle after taking the 3 minute pause into account was 99 dBA. This is equivalent to a noise dose of approximately 14% per cycle, (i.e. between rod changes) where 100% represents the maximum allowable daily noise dose without hearing protection. At the rate of three 16 ft cycles per hour, the maximum allowable noise exposure would be reached after approximately 2.5 hours of drilling. Actual noise exposures will vary with drilling conditions, number of delays encountered, etc. However, if the above rates were taken to represent the worst case, then noise doses which would be accumulated in 8, 10, and 12 hour drilling shifts would be 326%, 408% and 490%, respectively.

* Includes drilling a 16 ft length with a 2 ft stroke on the drill, disconnecting the water swivel, lowering the overshot, pulling the inner tube, exchanging inner tubes, pumping an empty inner tube back down the hole, and lowering the rods for resumption of drilling.

10.2 Preliminary Study of Modified Head Options

Having determined that spur gears or a chain drive in the front end and straight cut bevel gears in the head were the next noise sources requiring treatment after the power pack, it became necessary to explore what design options existed for alleviating problems in both of the above sections of the drill. Plans called for: (i) preliminary ideas to be put forward on the basis of previous discussions with the C.D.D.A. regarding overall design constraints, (ii) selection of the most promising of these ideas for further consideration on the basis of discussions with interested drill users, and (iii) exploration of the latter in close cooperation with Canadian drill manufacturers with the goal of arriving at the definition of a likely design configuration and cost. Attention was focused on the head initially, since it posed the greatest challenge.

Two considerations were deemed important at the outset: (i) that the type of gearing currently used is not the quietest available, and (ii) that repeated opening and closing of the swivel head is likely to result in misalignment or changes in tolerance of the gear system and loss of proper lubrication, which in turn probably aggravates the noise problem. After careful consideration of these two major points, it was decided that if at all possible, any design modification should keep the head gears in contact, thereby maintaining proper alignment at all times even when removing corebarrels. This, of course could be easily accomplished if movement of the complete drill could be tolerated during the corebarrel pulling process. Following many discussions, it was determined that this procedure, although occurring infrequently, was not favoured by users. Therefore, it was necessary to find a technique which would provide easy core removal through swivel head movement, while still maintaining gear contact at all times. The type of gears to be used, subject to final design considerations, would probably be spiral or hypoid bevel gears.

A number of alternatives were considered on the basis of where the drills were to be used the detailed operations to be performed by the driller, the difficulties or restrictions imposed by these design changes, the severity of the proposed changes (keeping retrofitting in mind), and the probable costs. Of all the alternatives considered, two were finally assessed as serious possibilities. These were:

(i) Telescoping of a closed head, using one of several possible linkages between the power shaft and head;

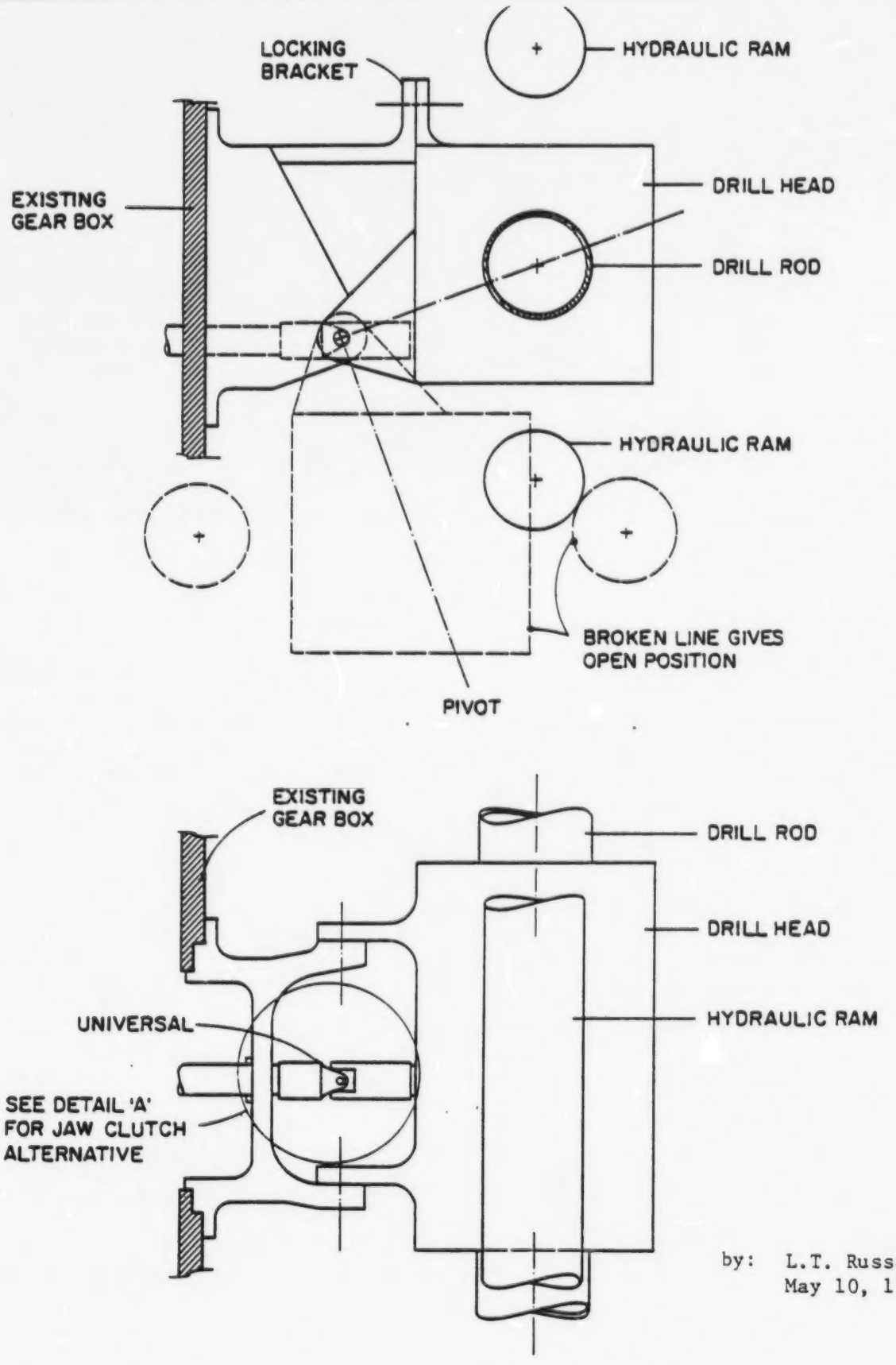
(ii) Swiveling of a closed head, using a universal joint in the power shaft to provide the linkage.

All of the above ideas were reviewed with personnel from a drilling contractor in order to obtain some user input before selecting the most promising options for further consideration. The second of the above approaches seemed preferable because it most closely resembled existing designs, and therefore seemed most likely to be accepted by drill users. Contractor personnel even suggested an alternate method for providing the linkage between the power shaft and the drill head([18]). Before continuing with the preliminary design work, however, more detailed engineering data on the existing drills (e.g. power delivered through head gears, limits of allowable gear ratio changes, detailed dimensional drawings which would enable the particulars and practicalities of contemplated design changes to be examined, etc.) had to be obtained. This information was requested, but unfortunately never received. Nonetheless, engineering sketches suitable for discussion purposes and illustrating the two chosen approaches, were prepared on the basis of information previously received in the form of photocopies of manufacturers' parts lists and repair manual excerpts. These sketches are reproduced as Figures 11 and 12, and are explained below.

Both approaches incorporate the closed and swiveling head features. Spiral or hypoid bevel gears are to be used inside the head, depending on where the location of the pivot point for swiveling the head is ultimately chosen. Either gear set should operate more quietly than the existing straight cut bevel gears. Moreover, the closed head feature should also be quieter as a result of improved gear alignment, better lubrication and reduced wear. Alternate linkages between the power shaft and head are shown. The first (Figure 11), is the universal joint solution mentioned previously. Note the offset power shaft and pivot point required to implement the desired swiveling feature. The second (Figure 12), uses a jaw clutch in place of a universal joint, and could be used to eliminate the need for an offset power shaft and pivot point if necessary.

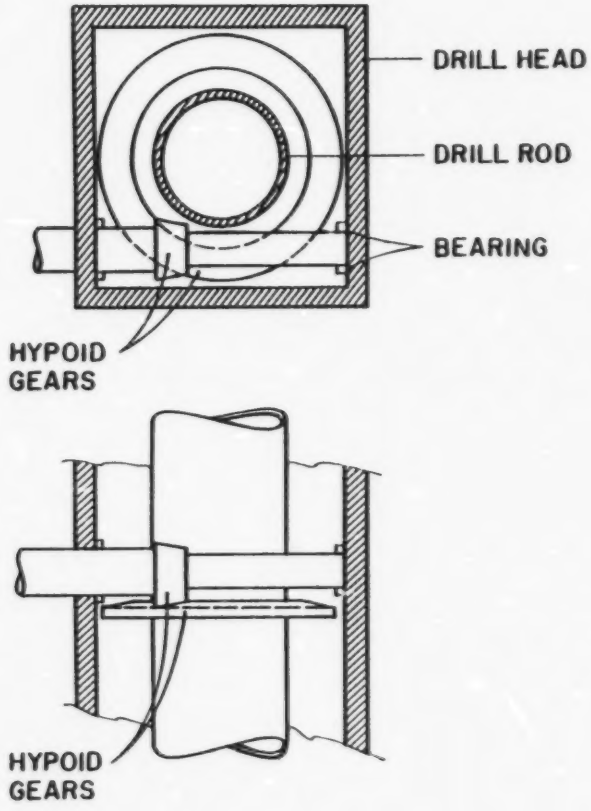
The above sketches were forwarded to the Technical Committee of the C.D.D.A. for comment by its members([20]), but only one reply was received([21]). This reply came from a drilling contractor, and raised several helpful and valid points about overall design considerations which were well worth further discussion with drill manufacturers, but posed no insurmountable problems so far as the basic concepts were concerned (particulars are included in Appendix D)([22]).

An opportunity to review these concepts with Canadian drill manufacturers arose in September during a meeting of the C.D.D.A. Technical Committee in Toronto. The two suggestions were discussed in depth with all aspects of the design receiving attention. Possible difficulties with these designs such as extra cost, large overhang of the head, extra strength required,



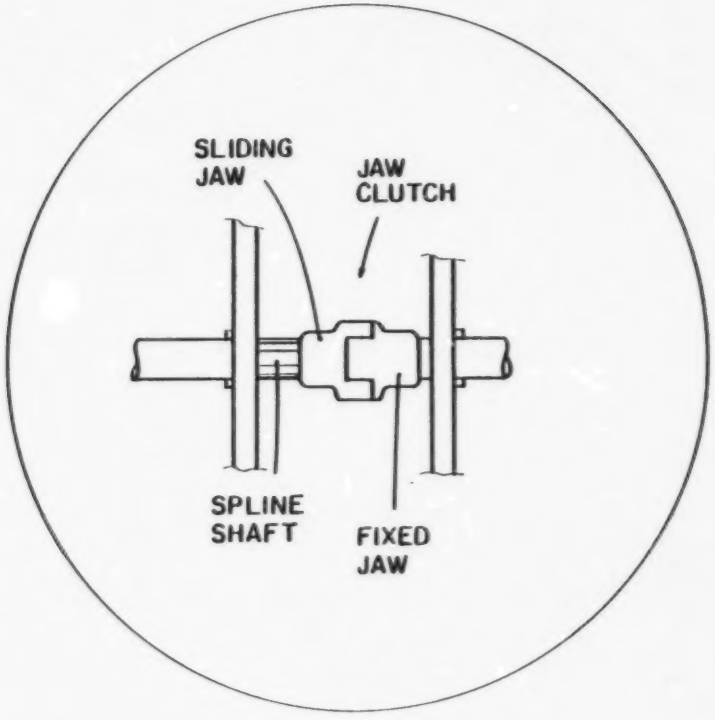
by: L.T. Russell
May 10, 1982

Fig. 11 - Closed Drill Head & Universal Joint Concepts



POSSIBLE DRILL HEAD GEARING ARRANGEMENT

NOTE WITH JAW CLUTCH, PIVOT POINT LOCATION IS NOT CRITICAL AND MAY BE LOCATED AT ANY CONVENIENT POINT.



DETAIL "A"

by: L.T. Russell
May 10, 1982

Fig. 12 - Drill Head Gearing and Alternate Power Shaft Linkage Arrangements

possible vibration in the head as a result of the changes, and the question of whether the changes could be incorporated into a retro-fit were all considered. A general conclusion seemed to be that the suggested design changes are technically feasible, but that a more in-depth study in cooperation with the manufacturer's designers will be necessary in order to determine the proper direction in which to proceed. Both manufacturers represented at that meeting felt that each company would probably cooperate with a more in-depth investigation, so a formal request to follow up with the required studies was made to each([23,24]). Subsequent replies were somewhat less enthusiastic([25,26]). As a result, a review of alternate approaches will be required in the future.

A lack of engineering details on front ends precluded any significant headway being made on the further study of possible design changes in front end gearing. Considerations in mind include substituting helical gears for the spur gears, use of "quiet" chain drives or chain drive shielding, etc.

10.3 Power Train & Head Options From Sprague & Henwood Inc.

Referring back to Figures 3 and 6, the front end and head assemblies for the Sprague and Henwood Models 142C and 40C drills can be seen. The Model 142C front end has been modified internally and fitted with a set of "quiet-operating" gears, details of which were not disclosed for proprietary reasons. The head has also been modified to accept a set of "carefully lapped" spiral bevel gears. By contrast, the front end of the Model 40C drill was left unmodified; however, the acoustical enclosure has been extended from the engine, along the drive shaft, up to and including the front end. The head was modified with a spiral bevel gear like that of the Model 142C.

Operating experience with both models has shown that the 142C is the more favoured of the two. The large engine enclosure and extended acoustical panels for the front end were found to be too bulky in the field and also encumbered routine maintenance. Some of these panels were finally removed by operating personnel, thereby defeating much of the noise control effort which had been made. However, the continued successful operation of the Model 142C is indeed very encouraging and demonstrates the technical feasibility of a compact acoustical engine enclosure and of quieter-operating gears in the front end and head. Both models are retractable drills with fixed heads. A unique movable tower feature has been provided on each model to compensate for offset created between the drill hole centre line and the sheave at the top of the tower when the drill is retracted.

Cost data for both models were also obtained and are discussed next. For now, it is worth noting that the total costs

for all of the noise control options did not exceed $5,000 U.S. (or ∿$6,000 CAN.). These figures barely account for the cost of materials and components involved, therefore indicating that substitution of quiet-operating gear sets must have been possible with very little change in the original gear boxes, and also demonstrate that retrofit noise contol is economically feasible.

Overall noise levels measured in the operator's position with the above noise control packages in place were 94.5 dBA on the Model 142C drill, and 90 dBA on the Model 40C([11]). The difference in noise levels is believed attributable to residual noise from the front end, although this observation remains to be proven by actual measurement. This also suggests that additional work must be done on the front end if a design goal of 90 dBA or less is to be achieved ultimately. The 90 dBA minimum observed on the Model 40C drill appears to be determined by the spiral bevel gear, although again, the latter observation remains to be proven. The above may also be evidence of the lowest gear noise level achievable by simple gear substitution. Nonetheless, both drills have demonstrated a very significant improvement over the 100-107 dBA previously observed on drills currently in use in Canada.

11. CURRENTLY AVAILABLE NOISE CONTROL OPTIONS

When discussing available noise control options, a distinction has to be made between new drills and existing drills. Much more latitude exists in improving the design of new drills because in this case options like the use of hydrostatics to eliminate front end noise, or placing of the power pack in a remote location can be considered. Also, new drills with demonstrated noise control features (e.g. Sprague & Henwood) can be obtained commercially. Since the findings of this study suggest that retrofit noise control on existing drills is indeed feasible, the remainder of the discussion will limit itself to options currently available for drills in the latter category. This, of course, imposes severe design constraints in that all suggested modifications must be completely compatible with existing equipment, and must be capable of retrofitting in the field, usually by the drill user himself.

11.1 Power Pack Alternatives

There is no doubt that the drill's power pack is a major noise source. Proper silencing involves the use of an effective engine enclosure, and not just exhaust mufflers. Users may choose between building engine enclosures for existing engines themselves, having enclosures built on their behalf by acoustical equipment suppliers, or replacing existing engines with factory-silenced diesels such as the ones used in the Hatz series of "Silent Power Packs".

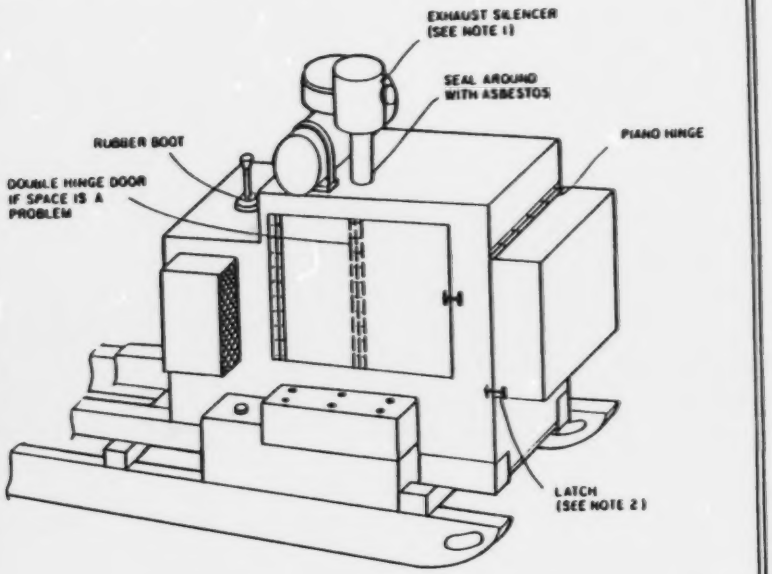
The salient features of the type of engine enclosure which could be fabricated and installed by users themselves are shown in Figure 13. In-house experience at Noranda has shown that an enclosure of this type could be fabricated and installed at a cost of approximately $5,000, including labour. Anyone choosing to go this route will require a limited amount of acoustical engineering supervision to ensure that when the general design of Figure 13 is adapted to a particular drill, the acoustical integrity of the enclosure remains intact. Experience has also shown that attempts to do without the recommended supervision usually results in technical oversights whose correction ultimately involves substantial extra project costs and frustrations.

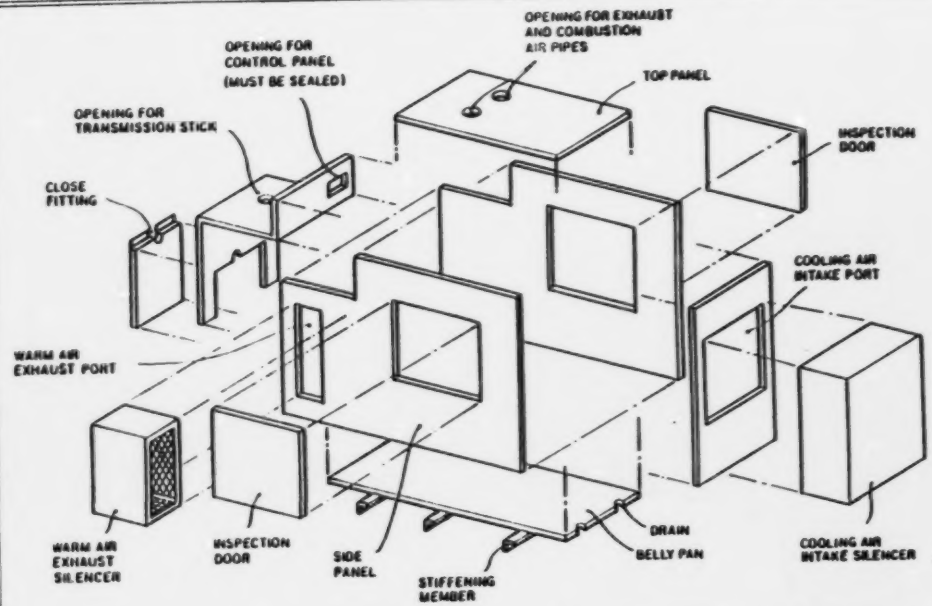
Preliminary quotations from acoustical equipment suppliers for the cost of providing a similar, although somewhat more complicated enclosure, indicated a probable cost of $12,000 per unit([2]). This figure basically reflects the cost of adapting general purpose acoustical panels to a particular application, plus the cost of materials involved. Unless the acoustical equipment suppliers can amortize their engineering costs over a reasonable number of units, it is unlikely that the above price will ever be less. The probability of this happening is believed to be slight because most drill users tend to customize their drills in some way (e.g. by mounting auxiliary hydraulic pumps or water pumps onto the standard drill), which means that practically every engine enclosure will require customized fitting. Hence, engineering charges will necessarily persist.

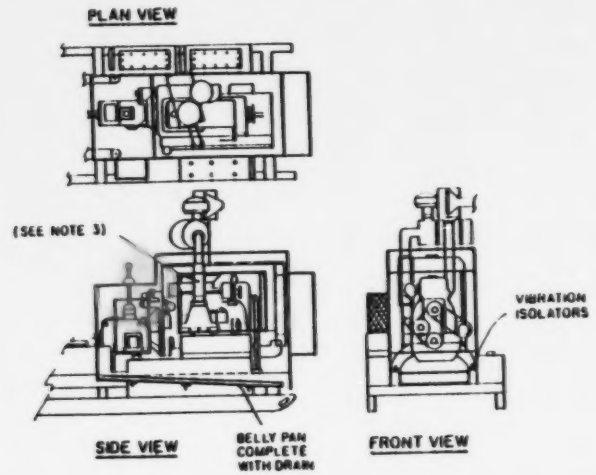
The cost of Hatz series L30 (30 - 60 HP) and L40 (40 - 80 HP) "Silent" diesels is in the order of $5,500 to $8,000, depending on the size of engine purchased, which is approximately 20 - 25% more than the cost of an equivalent regular diesel. If an existing engine needs replacing anyway, then purchasing a Hatz diesel already equipped with an engine enclosure would appear to be the most efficacious way of achieving power pack noise control. Otherwise, in-house fabrication of enclosures similar to that described in Figure 13 using outside acoustical engineering assistance as required would appear to be the best alternative.

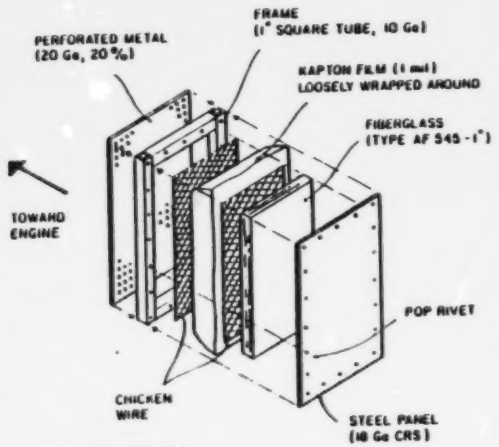
11.2 Front End Alternatives

Two approaches for treating front end noise have been demonstrated to date. One involves the use of acoustical panels to enclose most of the front end assembly, and the other the substitution of quiet (e.g. helical?) gears for the spur gears that are more typically found in front end transmissions. The former technique appears to have achieved the greatest noise reduction, but, unfortunately, was found to be impractical in the field. The latter technique has still to be demonstrated on typical Canadian drills. In addition, available data raise the question of how sensitive front end noise levels may be to proper


EXHAUST SILENCER (SEE NOTE 1)
SEAL AROUND WITH ASBESTOS
RUBBER BOOT
PIANO HINGE
DOUBLE HINGE DOOR IF SPACE IS A PROBLEM
LATCH (SEE NOTE 2)






PERFORATED METAL (20 Ga, 20 %)
FRAME (1" SQUARE TUBE, 10 Ga)
KAPTON FILM (1 mil) LOOSELY WRAPPED AROUND
FIBERGLASS (TYPE AF 545 - 1")
TOWARD ENGINE
POP RIVET
CHICKEN WIRE
STEEL PANEL (18 Ga CRS)

TYPICAL ACOUSTICAL PANEL CONSTRUCTION

NOTES:

ALL PANELS SHOWN IN EXPLODED VIEW (EXCEPT BELLY PAN) TO BE CONSTRUCTED AS PER TYPICAL ACOUSTICAL PANEL DETAIL. FINAL ARRANGEMENT TO BE SELECTED ON SITE.

1. EXHAUST SILENCER TYPE COWL TO BE PROPERLY SELECTED.
2. SOUTHCO INC. PART No. 37 - 10 - 086 - 10 OR EQUIVALENT.
3. COMBUSTION AIR INLET SILENCER ASSUMED, IF NOT ALREADY AVAILABLE ON DRILL, ONE MUST BE INSTALLED.

NORANDA RESEARCH CENTRE
POINTE CLAIRE, QUEBEC, CANADA

TITLE: ACOUSTICAL ENGINE ENCLOSURE FOR A DIESEL POWERED DIAMOND DRILL.

DRAWN BY: J. P. D.	APPROVED BY: P. NGUYEN	PROJECT No. M - 8235
SCALE: NONE	DATE: APRIL, 83	DRAWING No. 13

maintenance and lubrication (e.g. 91 dBA was measured on one Longyear 38, and 102-103 dBA on another). Although the use of quieter-operating gears in the front end appears to be the most promising route to pursue, potential technical problems relating to the required gear ratios, power transfer requirements, etc. remain to be explored, so specific recommendations cannot be made at this time. In light of Sprague & Henwood's positive experiences to date, a concerted effort to explore the full noise control potential of alternate gear sets should be considered in any future noise suppression studies on diamond drills.

11.3 Head Alternatives

Only one method of treating head noise has been proven to date, and it requires the use of spiral-cut bevel gears and a fixed head. Drill users have clearly expressed their preference for the retention of a swivel head over retractable drills (the only alternative at the moment) and preliminary studies have shown that provision of a swivelling, yet closed head assembly might be technically feasible, but will incur significant additional costs.

Until recently, all discussions with drill operators indicated that the only major drawback to switching to a retractable drill with a fixed head assembly, outside of potential cost, was the relative inconvenience of having to retract the drill as compared to simply swinging the head. Since most operators spoken to only had a need to swing the head two or three times per shift, switching to a fixed head seemed to be the most practical method of resolving bevel gear noise problems without unduly impacting current operating practices.

Discussions near the end of the contract period suggested another problem existed in connection with the drill tower, or derrick. It appears that the majority of surface drills in Canada have derricks which are attached to the drill itself. This feature facilitates alignment of the derrick and head assembly when drilling holes at angles other than 90° - which is usually the requirement in Canada due to the way mineralization most often occurs in the Precambrian Shield. Retraction of the drill under these circumstances will cause an offset to occur between the centre-line of the drill hole and the sheave mounted at the top of the derrick, thereby interfering with the pulling of the drill string. Thus, a means of compensating for the above offset is required.

Sprague & Henwood Inc. resolved this problem very nicely by installing pins at the base of the tower which allows the derrick to swing toward or away from the drill hole, all of which is supported on a yoke which allows rotation of the head and tower in unison for drilling angular holes. Movement of the derrick is controlled by two hydraulic cylinders (see Figure 3). The feasibility and cost of adapting similar designs to Canadian drills remain to be examined. However, the prospects of implementing similar changes appear favourable at this time.

Users will have to decide whether occasional retraction of the whole drill is a reasonable alternative to occasional swinging of the head. If so, then the introduction of spiral-cut bevel gears can probably be implemented in a fairly straightforward manner, and at a reasonable cost - although this view remains to be substantiated and should also be a part of any future studies on diamond drill noise control. The extent and cost of design changes to derricks will also have to be considered at this stage. If drill retraction is still deemed unacceptable, then suitable modified head assembly designs will have to be explored further with drill manufacturers, along with plans for eventually phasing out existing designs.

11.4 Water Pump Considerations

At least two methods of powering water pumps have been encountered on drills observed to date. One used a separate small diesel engine, while the other was driven by a hydraulic motor which in turn was powered by a hydraulic pump driven by the main diesel. In the former case, the water pump unit is a significant noise source and must be treated by means of an acoustical enclosure. A simplified version of the enclosure shown in Figure 13 should suffice. Depending on the pump's location with respect to the drill operator and shack, even simpler configurations may be possible.

The latter cases are not nearly so well defined. Noise emissions from the water pumps themselves or from the ancillary hydraulics were not discernible amidst the power pack, front end and head noise. Consequently, it is not possible to state with certainty at this time whether or not noise control will also be required on water pumps that are powered this way. The only advice which can be offered at this point is to include the water pump and hydraulics inside any newly installed engine enclosures, if convenient to do so, as a fail safe measure. Otherwise, one should wait until the need to treat this source has been substantiated.

11.5 Summary Of Cost Considerations

Sprague and Henwood have indicated the incremental costs for noise control treatments on their Models 142C and 40C drills to be $4,000 and $5,000 U.S., respectively (or approximately $4,800 and $6,000 CAN.).

On the Model 142C drill the above price includes:

- lining the standard John Deere engine enclosure with 1 in. soundfoam;
- one exhaust muffler;
- one combustion air inlet silencer;

- dampened-steel panels on the drill skid (beneath the engine);
- partial enclosures on two drive shaft couplings;
- vibration isolators under the engine and transmission;
- a "quiet" front end (i.e.with modified gear set);
- spiral bevel gears in the head.

On the Model 40C unit, the above price includes:

- a custom-designed acoustical engine enclosure;
- one exhaust muffler;
- one combustion air inlet silencer;
- vibration isolators under the engine and transmission;
- an acoustical enclosure around the power train and front end;
- spiral bevel gears.

Comparing the two drills, it is difficult to rationalize the small difference in price for the two noise treatments when one considers that the acoustical panels installed on the Model 40C unit obviously require much more material, cutting and fitting. Nonetheless, it is interesting to note that the cost of the more expensive treatment did not exceed $5,000.

Given the above figures, and the previous estimate for building an acoustical engine enclosure in-house, an estimated overall cost of $7 - 8,000 would appear to be a reasonable expectation for someone interested in installing his own engine enclosure and retrofitting existing gears in the front end and head with appropriate helical and spiral cut gears. This assumes that no significant changes have to be made to existing gear housings or derricks. Any costs associated with the latter would be extra. If a Hatz diesel were to be purchased instead of fabricating an enclosure for an existing engine, overall cost would rise to approximately $7,500 to $11,000, depending on the size of engine being purchased.

The purchase price of a new BBS-37, Longyear 38 or Sprague & Henwood 142C is approximately $50,000 ± 5,000 (CAN.$), depending on options selected. Assuming the purchase price of existing or future "silenced" diamond drills will never be less than $50,000, there would appear to be sufficient incentive for seriously considering retrofitting existing drills with noise controls. The margin is sufficiently large to also accommodate some expenditures on derrick modifications if necessary.

REFERENCES

1. Smith, E. P., Heathwood Engineering Associates Limited, Cyr, J. C. R., Noranda Research Centre, Diamond Drill Noise Study Phase 1, DSS Contract No. 22SQ.23440-9-9023, March 1981.

2. Smith, E. P., Davis, P. E., Heathwood Engineering Associates Limited, Cyr, J. C. R., Noranda Research Centre, Diamond Drill Noise Study Phase 2, DSS Contract No. 18SQ.23440-0-9044, March 1982.

3. Geller, L. B., Canada Centre for Mineral Engineering and Technology (CANMET), A Review of Diamond Drilling R & D Contracts Funded In 1973 to 1982 By the Canada Centre for Mineral and Energy Technology (CANMET), Report MRP/MRL 82-41 (OP), April 1982, presented to the 39th Annual Meeting and Convention of the Canadian Diamond Drilling Association, May 5 - 7, 1982, Montréal, Québec.

4. Odén, A., Craelius AB, letter to R. Cyr, 11 August, 1982.

5. Erwin, T. M., Drill Systems Inc., letter to R. Cyr, 13 August, 1982.

6. Norrick, R. F., Mobile Drilling Company Inc., letter to R. Cyr, 30 June, 1982.

7. Smith, M. F., English Drilling Equipment Co. Ltd., letter to R. Cyr, 7 July, 1982.

8. Slade, J. R., Duke & Ockenden Ltd., letter to R. Cyr, 28 June, 1982.

9. Morris, D., Christensen Diamond Products (UK) Ltd., letter to R. Cyr, 28 June, 1982.

10. Alders, R., B. V. Machinebouw Conrad-Stork, letter to R. Cyr, 28 June 1982.

11. Nguyen, P., Noranda Research Centre, Trip Report. Sprague & Henwood Inc., Scranton, PA, 14 September, 1982, 12 October, 1982.

12. Automotive Engineering, Volume 90, No. 10, October 1982, pp 116, 125, 127, 128.

13. Mining Equipment International, Volume 6, No. 7, July, 1982, p. 8.

14. Nguyen, P., Noranda Research Centre, Trip Report. Noise Suppression for Diamond Drilling Equipment, Highlights of Meeting with CANMET, Ottawa, 27 July, 1982, 15 August, 1982.

15. Leroux, G., Noranda Research Centre, Trip Report. St. Lambert Drilling Co. Ltd., 10 February, 1982, 25 February, 1982.

16. Leroux, G., Noranda Research Centre, Trip Report. SRS-900-1 Diamond Drilling Rig Noise Performance in the Field, 12 April, 1982.

17. Cyr, J. C. R., Robertson, R. J., Noranda Research Centre, Information Memorandum, Evaluation of the Performance of Hearing Protectors & General Recommendations for Their Selection and Use, 9 November, 1981.

18. Cyr, J. C. R., Noranda Research Centre, Trip Report. Highlights of Meetings with Dr. L. Russell and Logan Drilling Ltd., Halifax, 3 - 4 May, 1982, 10 May, 1982.

19. Leroux, G., Noranda Research Centre, letter to R. Cyr, 17 November, 1982.

20. Cyr, R., Noranda Research Centre, letter to L. Geller, May 1982.

21. Green, A., Morissette Diamond Drilling Ltd., letter to L. Geller, June 1982.

22. Russell, L. T., Technical University of Nova Scotia, letter to R. Cyr, 6 July, 1982.

23. Holland, D., Canadian Diamond Drilling Association, letter to Dresser Industries (Canada) Limited, 18 October, 1982.

24. Holland, D., Canadian Diamond Drilling Association, letter to Longyear Canada Inc., 18 October, 1982.

25. Lawson, D., Dresser Industries (Canada) Limited, letter to D. Holland, 29 October, 1982.

26. Merriman, V. L., Longyear Canada Inc., letter to D. Holland, 11 November, 1982.

APPENDIX A

SAMPLE LETTER TO INTERNATIONAL DIAMOND DRILL MANUFACTURERS

&

SUMMARY OF REPLIES

240 boulevard Hymus
Pointe-Claire, Québec H9R 1G5
Tél. (514) 697-6640
Télex 05-822647

noranda

16 June 1982

Christensen Diamond Products
Govett Avenue,
Shepperton,
Surrey, England, UK

Dear Sir:

The Noranda Research Centre is conducting a survey of diamond drill manufacturers on behalf of the Canadian Federal Government to determine the state-of-the-art vis-à-vis noise controls for diesel-powered diamond drills. If you have already developed and implemented noise controls for diesel power packs, the power train, and/or the head, or plan to in the reasonably near future, we would be pleased to hear from you and include your comments in our report. The information should include a description of design changes that were made for noise control purposes, before and after noise level measurements, supporting pictures, sketches, etc. so that your improvements can be accurately described to others. We plan to report our findings in September, so any information you may wish to contribute should be forwarded to us no later than mid-August.

Thanking you in advance for your cooperation.

Yours truly,

R. Cyr
Group Leader,
Noise Abatement & Industrial Hygiene

RC/sp

FIGURE A-1 - Sample Letter

To Diamond Drill Manufacturers

TABLE A-1 - DIAMOND DRILL MANUFACTURERS SURVEYED REGARDING EXISTING OR PLANNED NOISE CONTROLS

	COMPANIES	REPLY RECEIVED ?	NOISE CONTROLS DESCRIBED & COMMENTS
1	Atlas Copco Canada Ltd. Montréal, Québec	Yes	No longer manufacture complete diamond drills, only some components.
2	Acker Drill Co. Scranton, PA.	Yes	Spiral cut bevel gear inside a fixed head. No performance data available. Interested in Canadian progress.
3.	Becker Drills Inc Denver, CO	No	
4.	Boart International Windsor, England	Yes	Referred author to Longyear Canada Inc., an affiliate.
5.	Bucyrus-Erie Co Milwaukee, Wis.	No	
6.	Christensen Diamond Products Surrey, England	Yes	Do not manufacture drills, but indicated British Drilling Association will include noise as a required specification in a proposed "Drill Rig Rating". Expressed interest in Canadian progress.
7	Craelius AB, Bromma, Sweden	Yes	Provide option of sound-proofing on remote power packs for smaller (ie. 400m) hydraulic drills. Expressed interest in Canadian progress.
8.	Diamant Boart Brussels, Belgium	No	
9.	Dresser Industries Canada Ltd. Orillia, Ont.	Yes	No new developments.
10	Drill Systems Inc. Calgary, Alta.	Yes	Have used helical gears and pressure lubrication in the main gearbox of a dual tube drilling r: Also substituted hydraulics for a chain drive, muffled the power pac exhaust, and remotely locate both the power pack and compressor package. No performance data available.

(TABLE A-1 Cont'd)

11. Duke & Ockenden Ltd. Sussex, England	Yes	Provide sound-proofed power pack option on their hydraulic drill
12. English Drilling Equipment Co. Ltd., Yorks, England	Yes	Currently examining prospects of providing sound-proofed power pack.
13. Fox Manufacturing Co. Smithfield, Australia	No	
14. Longyear Canada Inc. North Bay, Ontario	Yes	Have experimented with gears in gear train, but particulars remain unspecified.
15. Mobile Drilling Indianapolis Ind.	Yes	Provide engine exhaust muffler upon request and label drills with warning sign indicating hearing protection must be worn. Expressed interest in Canadian progress.
16. Moss (Pty.) Ltd. Mt. Hawthorn, Australia	No	
17. Salisbury & Dietz Inc. Spokane WA.	No	
18. Smith International Inc. Newport Beach, CA.	No	
19. Soding & Halbach; Hagen Fed. Rep. Germany	No	
20. Sprague & Henwood Inc. Scranton, PA	Yes	Will provide complete drill enclosure or engine enclosure only. Will also provide helical gears in front end and spiral cut bevel gears in a fixed head. Expressed interest in Canadian progress.
21. Stork BV, Haarlem, Netherlands	Yes	Do not manufacture diamond drills.
22. Thiele, Wilby, Bohrunternehmen, Bremer, Fed Rep. Germany	No	
23. Van-Moppes, Idp. Ltd. Gloucester, England	No	
24. Walkes-Mear Manufacturing Wichita Falls, TX.	No	

APPENDIX B

SAMPLE LETTER TO DIESEL ENGINE MANUFACTURERS & MANUFACTURERS' REPLIES

Centre de Recherche Noranda
240 boulevard Hymus
Pointe Claire, Québec H9R 1G5
Tél. (514) 697-6640

Twx 610-422-3826
Telex: 05 24352 NORANDA MTL

B-1

noranda

7 April 1982

Mr. J. Stimson
Noise Engineer
Deutz Diesel (Canada) Ltd.
90 Montée de Liesse
Ville St. Laurent, Québec
H4T 1N4

cc: L. Geller (Canmet)
K. Wheeland

Dear Mr. Stimson,

Our Research Centre is conducting a study of engineering noise control methods for diamond drilling equipment on behalf of the Canadian Federal Government. We find that the class of drill most extensively used across Canada is powered by air or water-cooled diesel engines, typically in the 50 to 100 HP range. Perhaps not too surprisingly, we also find that the power pack is one of the key noise sources.

An acoustical engine enclosure is being developed as a retrofit package for existing drills. However, we were wondering if there would be any prospect of eventually expecting a 'quiet' diesel engine of this size range on the market (ie. one whose noise emissions do not exceed 85 dBA). Such an engine would obviate the need of, and added maintenance and costs associated with, an 'add-on' noise control package.

I would appreciate your comments concerning your company's existing or planned R & D programs in this area, along with some indication of probable timing re product availability, if indeed a program is underway. This information will be included in our final report at year end.

Looking forward to hearing from you, I remain,

Yours truly,

R. Cyr, Group Leader,
Noise Abatement Technology and
Industrial Hygiene.

RC/sp

Detroit Diesel Allison
Division of General Motors Corporation

General Offices
13400 West Outer Drive
Detroit, Michigan 48228
Phone: (313) 592-5000
Telex: 234019
TWX: 810-221-1649

June 1, 1982

Mr. R. Cyr
Noranda
240 Boulevard Hymus
Pointe Claire, Quebec
H9R 1G5

Dear Mr. Cyr:

Please find enclosed the noise data you requested from General Motors on April 7, 1982. The data reflects projections for our line of small industrial diesel engines. Thank you for including us in your study.

Sincerely,

Tedd D. Grulke

Enclosure
TDG/jm

PROJECTED NOISE LEVELS FOR FORWARD PLAN

INCLUDES: ISOLATED ROCKER COVER & OIL PAN, CROSSHEAD PISTONS & OTHER ENGINE TREATMENTS.

CURRENT ENGINE	db(A)	PERCENT REDUCTION	REDUCED SPEED EFFECT	db(A)	PERCENT REDUCTION
3-53T @ 2500	93.0	56	3-53T @ 2200	91.0	37
4-53T @ 2500	97.0	62	4-53T @ 2200	95.0	37
6V-53T @ 2500	96.0	59	6V-53T @ 2200	94.0	37

BARE ENGINE S.P.L. MEASURED @ 1 METER PER SAE J-1074

B-4

Ford of Europe Incorporated
Industrial Products Engineering

Arisdale Avenue
South Ockendon Essex RM15 5TJ
Telephone: South Ockendon
(0708) 853434
Telex: 995511

June 11, 1982

Centrede Recherche Noranda
240 boulevard Hymus
Point Claire
Quebec H9R 1G5
Canada

Attn: Mr R Cyr

Dear Sir,

Thank you for your letter of 7th April 1982 which has been passed to me for action.

There is increasing pressure in the field to reduce noise emanating from industrial equipment and legislation is progressively more stringent. In order to comply with such conditions most manufacturers find that improvements in equipment design must be made on a continuing basis in addition to that required for other reasons.

Ford Motor Company has recently introduced the 2720 Range of diesel engines to replace the 2710 Range with significantly reduced noise emissions.

The new 4 cylinder engine known as the 2722 which is most likely to be in the power range you require, has a 3m noise figure in the low 90's dB(A) depending upon speed. This is still somewhat above your target. Furthermore the engine requires a cooling fan, which is usually a major noise source compared to the engine and will drive a compressor hydraulic pump or other such equipment which could contribute significantly to the overall noise level.

As far as the future is concerned Ford Motor Company will of course endeavour to tailor its products to meet market and legislative requirements but I am not in a position to give you any particular details.

Yours faithfully,

K J Winter
Installation Engineer
Industrial Products Engineering

cc: J S Brown D-MW/GS-20
J C Moss GB-11/129

HATZ ... KG
RUHSTORF..ROTT

Telefon Pocking (08531) 3021
telex Verkauf/Buchhaltung 057260
telex Einkauf/Konstrukt 057268
Draht Hatzmotor Ruhstorfadrott
Bahnstation Ruhstorf

Bayer. Vereinsbank Passau Kto.-Nr 2817780, BLZ 74020074
Dresdner Bank Regensburg, Kto.-Nr 1915071, BLZ 75080003
Kreissparkasse Ruhstorf Kto.-Nr 570100800, BLZ 74050000
Deutsche Bank Straubing, Kto.-Nr 98/21471 BLZ 74270015
Postscheckkonto München [illegible]

B-5

HATZ DIESEL

MOTORENFABRIK HATZ GMBH ...
D-8399 RUHSTORF a. d. R...

Ihre Zeichen	Ihre Nachricht vom	Unsere Zeichen	8399 Ruhstorf
Betreff		MK/ME/Hör/ko	November 24,1982

Subject: SILENT POWER SYSTEM
Engine Families L 30 / L 40

Ladies and Gentlemen:

To the already existing SILENT POWER SYSTEM engines we have added further three engine types which now cover a range of 10 to 50 kW (approx. 15 to 70 HP).

Enclosed you will find the new leaflet of our SILENT POWER SYSTEM. With this letter we like to repeat once more the outstanding features of this engine series:

1) Whatever your needs may be, one of our six engines in the range of 10 to 50 kW can always offer you an optimum in price and performance. There is no other manufacturer who can offer you a similar density in this HP-range.

2) A significant data and a measurement for the ability of an engine to operate safe and reliable on high speeds is the mean piston speed. The L 30 / L 40 engines are designed to feature a low mean piston speed of only 10/10.5 m/sec at 3000 r.p. m. (compared to 12 m/sec for engines which have, for example, a stroke of 120 mm). This makes the L 30/ L 40 engines so durable when it comes to applications where high speed is required.

3) A wide range of additional equipment is offered for the L 30 / L 40 engine family which is individually adaptable for various applications. This is not only true for stationary application but also for mobile machinery, using hydraulic drives. We offer, for example, a hydraulic oilcooler with an electric fan which provides the full cooling performance, independent of engine speed. The electric fan needs only 10 to 20 % of the

alternator performance which still leaves you sufficient output to cover all remaining electric consumers.

4) The noise reduction of the encapsulated SILENT PACKS is most evident by the following example: 10 SILENT PACKS do not make more noise than one conventional Diesel engine! Wherever strict noise regulations apply, the SILENT PACK offers the perfect solution. The maintenance- and service points of a SILENT PACK are just as accessible as they are for any other HATZ Diesel engine.

5) The engine family L 30 / L 40 is developped with view to future legislation on protection of the environment. Not only with regard to noise but also the exhaust gas pollution is kept to a minimum. Furthermore, the engines feature a closed crankcase breathing system, as there are some countries which do no longer allow crankcase breathing into the free atmosphere.

6) Most modern production technology paired with a high standard quality control system ensures a high reliability.

Last, but not least - a most important point when choosing a Diesel engine is also the service which can be offered. HATZ Diesel engines are taken care of through our network almost all over the world!

Yours sincerely,

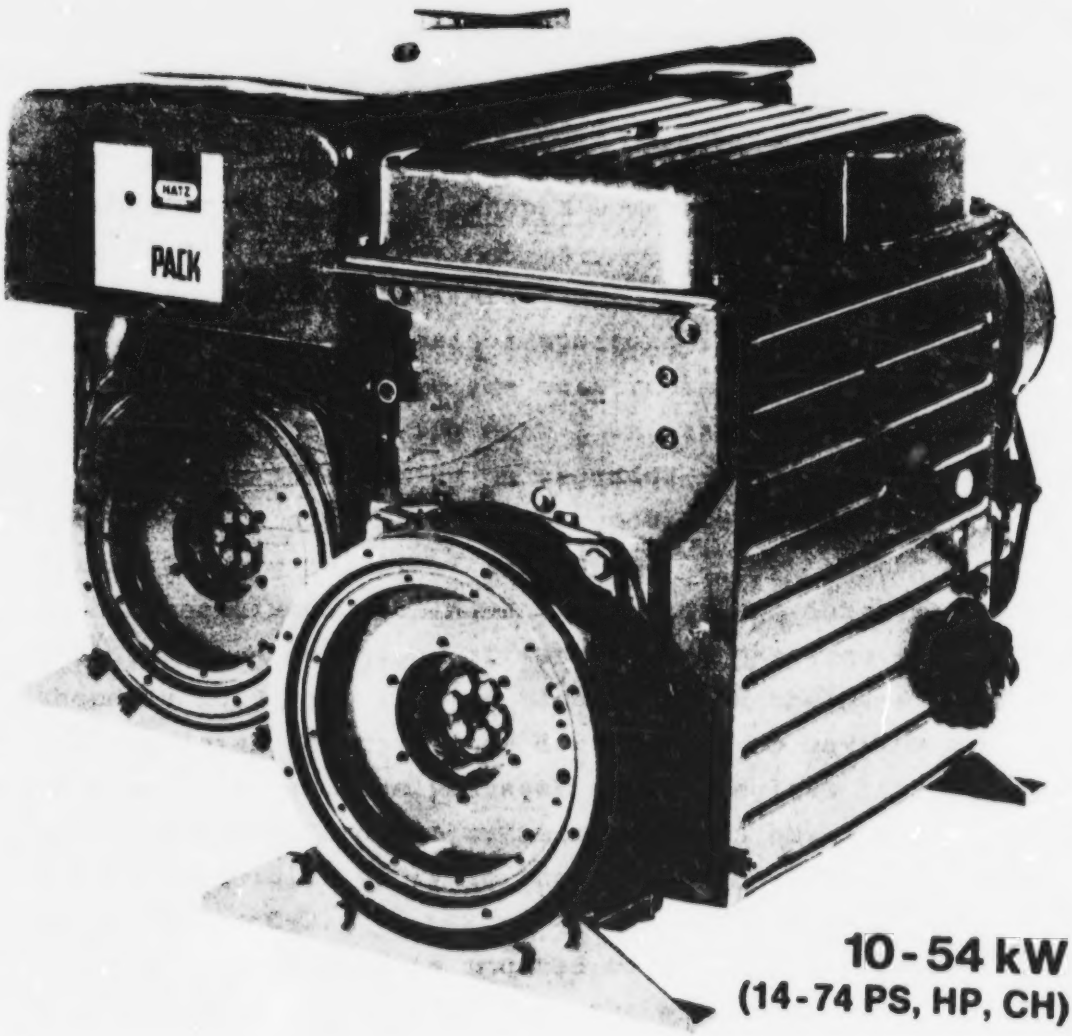
MOTOREN FABRIK HATZ
GmbH & Co. KG

ppa. i.V.

C. Steppacher J. Horner

Enclosure
Leaflet
SILENT POWER SYSTEM

HATZ SILENT PACK



10 - 54 kW
(14 - 74 PS, HP, CH)

APPENDIX C

DETAILS OF PROTOTYPE ENGINE ENCLOSURE BY CANMET

DETAILS OF PROTOTYPE ENGINE ENCLOSURE BY CANMET

So far CANMET has built one prototype version of a sound-suppression enclosure around the entire diesel-engine cum automotive transmission unit on loan, including the diesel-fuel and hydraulic-fluid tanks, battery, etc. Close liaison was maintained throughout, and much helpful advice received from, the acoustics section of NRC's division of physics, from C.D.D.A. members (representing both their manufacturing and contracting membership) and the project-contractors (Noranda Research).

Overall details of the sound-enclosure in question are illustrated in Figs. C-1 to C-13.

Salient features are as follows:

a) A 48" x 120" x 3/8" steel plate is placed underneath the entire diamond-drill assembly, shaped somewhat like a "stone-boat" (Fig. C-1).

b) Six anti-vibration pads are placed between the 3/8" base plate and the unit's main supporting skids (Fig. C-5).*

c) Panels of the enclosure are constructed of 16 ga. sheet metal, lined on the engine-side with 1 in. thick fibreglass, the latter being retained by an expanded-metal mesh. One large panel on each side is readily removable for easy engine access (Figs. C-11 to C-13).

d) To allow radiator cooling-air to enter and leave the enclosure without noise emission, offset ducting passages ensure that there is no direct line of sight between the panel openings and the noise source. Also duct length to maximum duct width is about 3:1, and the passages are fibreglass lined. Duct cross-sectional area to radiator-area is about 2:1. The same design principles apply to the combustion-air inlet duct (Figs. C-1 & C-2).

e) The entire enclosure is mounted on the 3/8 in. base-plate, i.e. an effort was made to decouple the enclosure from the vibrating components.

---

* These were subsequently replaced with 4 pads between the engine and skid.

f) Bulkhead fittings are mounted wherever hydraulic hoses pass through the enclosure.

g) The enclosure is designed for relatively easy assembly and disassembly. Rugged field operating conditions, mobility and space-limitations have also been considered, as far as was possible at this preliminary stage.

As a general guide to future efforts in this area, it may be noted that by April 1982 CANMET had invested about 792 man-hours of labour and $1,900 in material costs to build and test this enclosure, i.e. some $11,000 overall. However, of this amount about 120 man-hours were spent in overcoming difficulties experienced when direct coupling the diesel to the test-dynamometer. As for some of the major material costs, the original six vibration-pads cost some $317, muffler and exhaust piping $349, hose-fittings $112, Kapton sheeting $280, fibreglass lining $65, Marinite sheeting $108, 3/8" base-plate $214, 16 ga. sheeting $223, expanded metal $141 and welding electrodes $44.

The sound proofing qualities of the enclosure were tested by removing the BBS-37 diamond-drill unit and direct coupling the sound-canopy enclosed GM 353 plus automotive transmission unit to an electric dynamometer (Figs. C-7 to C-10). The principal test objectives were to determine the overall noise level as a function of diesel engine speed and loading. Moreover, if the overall noise-level was still in excess of the legal limit (90 dBA/8 hr. shift in Ontario), it was necessary to pin-point the reasons for this.

Diesel Engine Enclosure Testing

The tests were conducted in CANMET's laboratories (Figs. C-7 to C-10). The engine was mounted in a concrete-bunker and direct coupled to a dynamometer. The reverberations inside this enclosed space increased the noise level readings by 4 to 5 dBA within the frequency range of primary interest, as compared to readings in an open field. However, the usual drill-shack walls will also increase the

engine's noise level by several dB. The tests were controlled from an adjoining instrumentation room. Apart from the usual dynamometer read-outs (such as rpm and torque) a number of thermocouples were also mounted, to monitor critical temperatures, including the following: ambient within the bunker, radiator cooling air outlet, diesel-fuel (in tank), hydraulic fluid (in return tank), general air-temperature inside sound-enclosure, exhaust gas temperature and muffler wall temperature. The engine-radiator's coolant temperature-gauge was also carefully monitored.

The general no-load noise level before mounting the enclosure was measured at 90 dBA and 105 dBA at idling and full engine throttle speeds respectively, without any muffler on the engine. On mounting a GM recommended double-wrapped muffler (model 190-9419, type G) these values were reduced to 88 and 102 dBA respectively.

As mentioned, much time was spent in overcoming difficulties encountered with lining up and coupling of the diesel-engine and dynamometer shafts. Consequently, and also because of other urgent commitments, only some 2-1/2 to 3 hrs could be spent on actual noise tests under a range of speed and loading conditions. Even so the following results can already be reported:

a) The engine noise is influenced primarily by the speed at which it is operating. Loading seems to be of secondary, if not negligible, importance (Fig. C-14).

b) Although a torque range from no-load to 300 ft-lb was tested, this was done only in first gear, i.e., at the lowest output-shaft speed (400 rpm); consequently it only represents a range from no-load to some 23 hp. In fourth-gear (2200 rpm output-shaft speed) the maximum loading tested was 90 ft-lb, i.e. some 38 hp. In other words, the engine was not loaded to anywhere near its full capacity of some 90 hp. Consequently, the question of noise levels as a function of higher loading conditions is, as yet, unanswered.

c) The design steps taken to muffle the engine noise were satisfactory on five of the six sides enclosed. Even the special

problems posed by the combustion-air intake and combustion-gas outlet, the hydraulic hose passages through the enclosure, and the radiator cooling-air inlet and outlet ductings were satisfactorily overcome. Yet the remaining few percents of opening left around the drive-shaft, engine frame, main skids and throttle control levers let enough sound-energy escape to produce an overall noise-level in excess of the legally specified 90 dBA per 8 hr shift. This fact serves as a powerful reminder of the major difficulties involved in noise-suppression work, and that no opening, no matter how minor, can be left unplugged.

d) The dBA levels recorded in Fig. C-14 were measured at the radiator-air intake point, i.e. on the opposite side to where most of the noise was still escaping. In the operator's position the sound-level readings were some 5 to 7 dBA higher. Even so the noise level at full throttle no-load condition was reduced from the original "as received" value of 105 dBA to 93 dBA (at the air-inlet position), a considerable reduction when remembering that every change of 3 dBA means a halving (or doubling) of the sound-energy level measured.

e) While further design improvements are required on the operator's end of the enclosure to reduce the noise level to within legal limits, monitoring of the diesel-fuel, hydraulic fluid and several air and gas temperatures disclosed another problem as well, namely that the diesel-fuel overheated inside the enclosure. Its temperature rose to 163^{o}F within about an hour of operation. During the same time the bunker ambient air-temperature rose from 52 to 81^{o}F, the air temperature within the sound enclosure from 71 to 139^{o}F, the return hydraulic fluid temperature from 65 to 104^{o}F, the radiator cooling-air outlet temperature from 70 to 124^{o}F, the diesel exhaust gas temperature from 345 to 668^{o}F and the metal surface temperature of the exhaust muffler from 92 to 220^{o}F. The engine radiator coolant temperature remained steady at 180 to 185^{o}F throughout the tests. To overcome the problem with excessive diesel fuel temperatures the tank inside the enclosure was by-passed; a large fuel tank

was used instead, located outside of the sound-enclosure. This way fuel temperatures rose from an initial 79°F to only 102°F within some 1-1/2 hours of testing.

f) Apart from the overall sound-level measurements taken at the radiator air-inlet position an octave-band and individual frequency noise level scan was also performed at this location.

Results of the octave-band measurements are shown in Table C1.

TABLE C1 - Octave-band measurements at engine radiator air-inlet

Octave Band Centre Frequency (Hz)	Noise Level (dB)
31.5	68
63	90
125	94
250	92
500	92
1000	90
2000	85
4000	79
8000	68
16000	58
31500	39

As may be seen the excessive noise-levels are in the frequency range that is most annoying.

Measurements were also taken at the radiator air inlet position, at no-load fully open throttle conditions. The corresponding overall sound level reading was 93-1/2 dBA and 98-1/2 dB.

Silencing of the water-pump unit should then present no great difficulties, either by building a suitable enclosure around it, or by using a factory silenced diesel.

Fig. C-1 - Drill Rig in Early State of Refrofit
Note Stone boat and beginning of cooling-air inlet constructions & fuel and hydraulic oil tanks alongside of engine which were eventually built into enclosure.

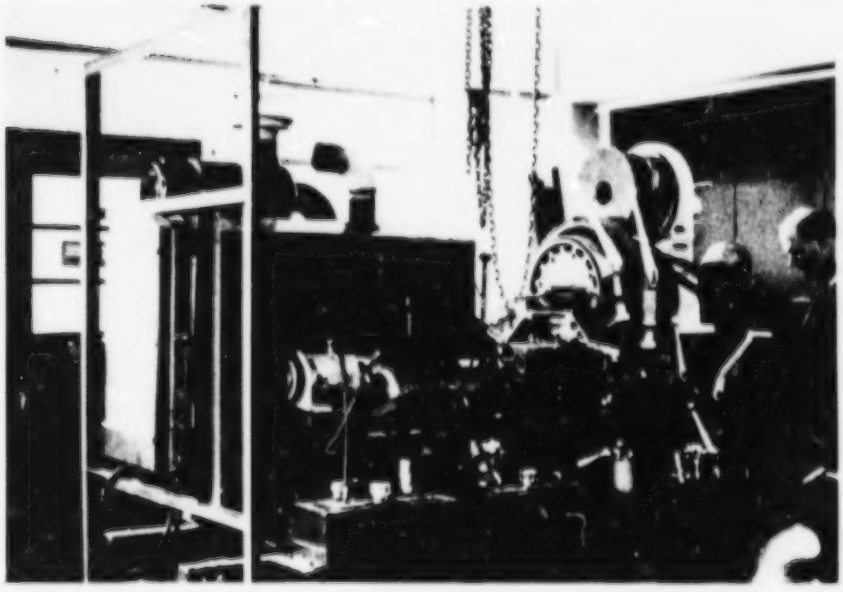


Fig. C-2 - End View of Engine Before Retrofit
Note Combustion air inlet filter & inlet on top of engine (background) and engine exhaust pipe (foreground).

Fig. C-3 - Close-Up of Engine Radiator
Note Hydraulic fluid cooler in front of radiator.

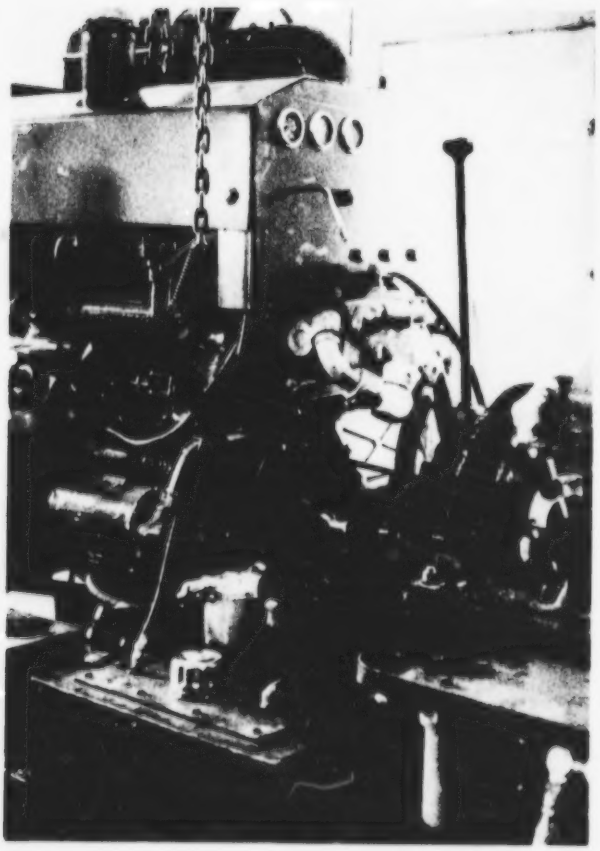


Fig. C-4 - Close-Up of Automotive Transmission Area
Note the complexity of linkages, etc. when considering interfacing with an acoustical enclosure.

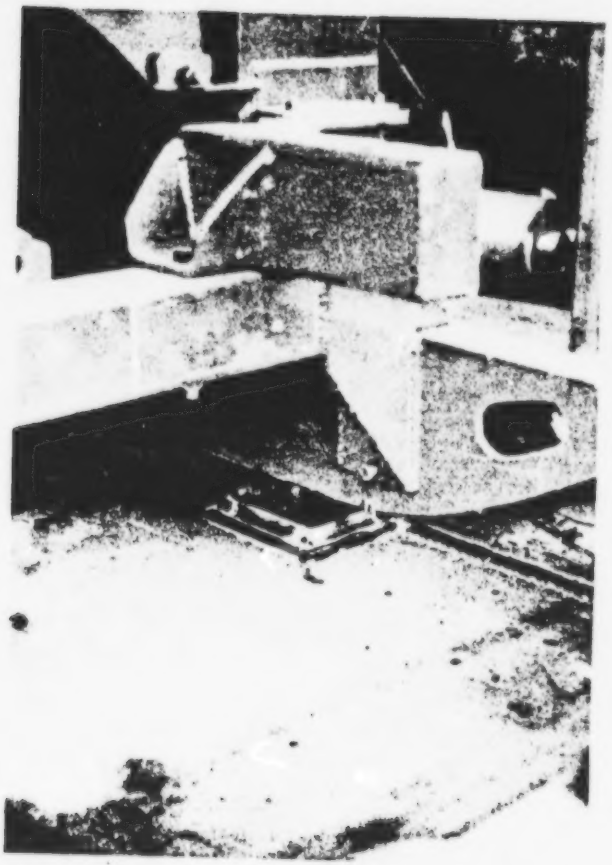


Fig. C-5 - Close-Up of Vibration Isolation Pad Used Between Stone Boat and Original Drill Skid

(subsequently relocated between engine & skid)

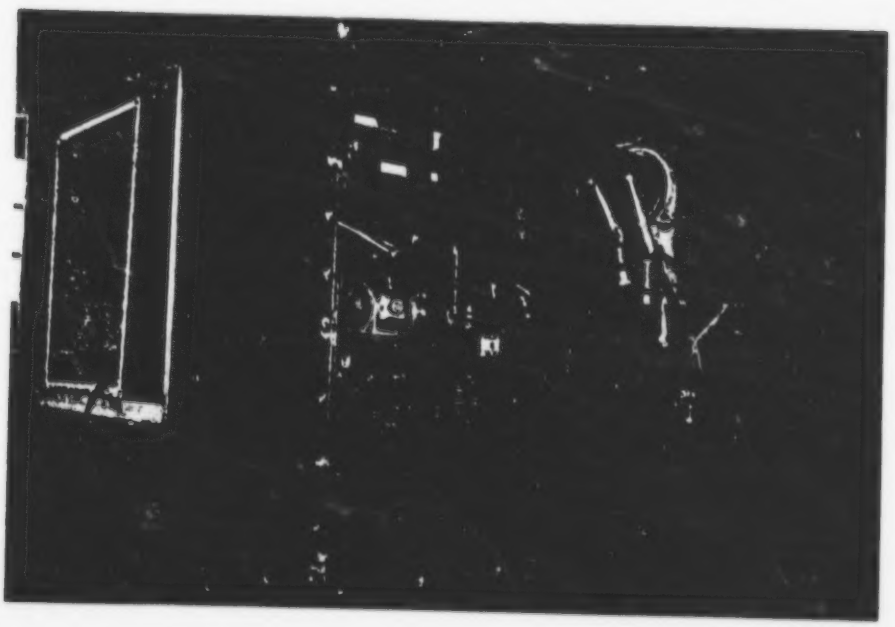


Fig. C-6 - Side Panels and Labyrinth Cooling Air Intake Beginning to Take Shape

Fig. C-7 - Partially Finished Enclosed Engine Being Delivered to Canmet Dynamometer Test Facilities for Noise Vs Load Tests

Fig. C-8 - Enclosed Engine Installed in Dynamometer Test Cell

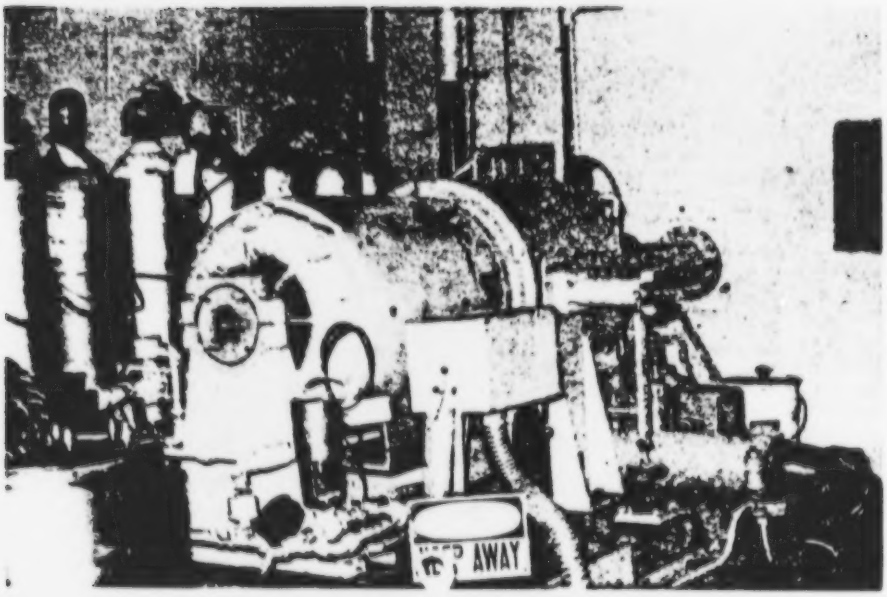


Fig. C-9 - Dynamometer

Fig. C-10 - Dynamometer Control Room

Fig. C-11 - Finished Prototype Enclosure - Frontside View

Note warm air exhaust grill and ducting on top of enclosure (foreground). Exhaust muffler is also enclosed - see rectangular construction to the immediate left of warm air exhaust grill (with exhaust pipe projecting). Note removable inspection panels.

Fig. C-12 - Finished Prototype Enclosure - Backside View
Note removable inspection panel.

Fig. C-13 - Finished Prototype Enclosure - End View

Note cooling air inlet grill, removable inspection panel, muffler enclosure and exhaust pipe.

APPENDIX D

CORRESPONDENCE REGARDING PRELIMINARY DESIGN CONCEPTS FOR A CLOSED SWIVEL HEAD

June 1982

Comments re the Proposed Changes for Noise Suppression on Drill Rigs

The idea of helical matched bevel gears would remove most of the noise from this source.

The disadvantages of helical bevel gears are the cost and ratio problems.

You cannot replace this type of gear without a matched replacement. This means a complete tear down of the swivel-head. If either gear becomes damaged and the adjustments on the matched helical gears must be set by dial indicator, a job that the driller might find hard to do.

Most helical bevel gears have a much smaller pinion gear than the crown gear. This would not be possible in diamond drilling as the speed of the drive rod would be too slow.

The configuration on the installation of a pinion the correct ratio size could cause a room problem.

The principle of the hinged slip joint drive would allow you to seal up the crown and pinion drive compartment thereby being able to properly keep lubrication in this area.

One of the major problems with this design is the amount of projection required causing an excessive overhang of the swivelhead. This would lead to excessive vibration and other related drilling problems. This would also make the engineering and fabricating costs very high.

On most drill swivelheads the greatest weakness is the poor supporting design of the drivesleeve bearings. These should be double row ball bearing with a wide supporting area on the drivesleeve. This would also reduce noise and vibration and possibly double the life of the swivelhead components.

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July 6, 1982.

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Dear Bob,

I received your memo with the comments of Mr. Allen Green and agree with you that the comments are, in general, well considered and constructive. In order to address them properly, I have numbered them and will refer to them one at a time.

1. Mr. Green agrees with our opinion that the use of helical matched bevel gears will remove most of the head noise and, hence, we start on a positive note.

2. At first sight, the disadvantage noted here with regard to cost may really be minor when consideration of replacement costs, down time, etc. are considered. I agree that the cost of the helical matched bevel gears will be higher than the straight bevel gears, but it has yet to be determined by how much. Now the ratio problem: This may indeed be a problem and will depend on what output speed can be delivered from the gear box, if any speed changes can be made within the box and what the necessary drilling speeds are. This can only be addressed at a more involved design stage.

3. I agree with number 3 with the added comment that the helical matched bevel gears may indeed last longer and require less frequent replacement and also I am not certain that replacement by the driller would be that unacceptable.

4. In general, this statement is true, but only detailed design would show if the drive rod speed could be maintained within an acceptable range.

5. Again a detailed design consideration. May or may not be a problem.

6. I agree, as this was the intent. This concept may also be useful with the present gearing in order to maintain proper alignment and tolerances.

7. The extra projection noted here as necessary may cause too large an overhang, but again I am not sure what extra overhang is required at this stage. As Mr. Green states, it may be a problem, but then again it may not be a problem. The comment regarding fabricating costs is, at best, at this stage a guess and I would feel that we must get deeper into the approach before this comment could really be seriously considered.

Cont'd p. 2 ...

8. I certainly agree with this comment regarding bearing types and I note in passing that one or two of the existing shafts within the system are certainly not supported in the best way in this regard.

I am very pleased that we have been able to receive comments like those given by Mr. Green. It appears to me that we are making some definite progress in at least seriously considering possible alternatives.

Yours sincerely,

Leslie T. Russell, Ph.D., P.Eng.

LTR/wr

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